REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
26-06-2009

2. REPORT TYPE
FINAL REPORT

3. DATES COVERED *(From - To)*
JULY 2008 to JULY 2009

4. TITLE AND SUBTITLE
A case study to improve emergency room patient flow at Womack Army Medical Center

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
REYNOLDS, DANIEL E., MAJ, US Army Medical Service Corps

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
WOMACK ARMY MEDICAL CENTER
2817 REILLY ROAD
FORT BRAGG, NC 28310

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Medical Department Center and School; BLDG 2841 MCCS-HE-HA (Army-Baylor Program in Health and Business Administration); 3151 Scott Road, Suite 1411; Fort Sam Houston, TX 78234-6135

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
2-09

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

20100329205

14. ABSTRACT
This graduate project is a case study on how to improve patient flow in the emergency department (ED) at Womack Army Medical Center (WAMC). Results of the case study indicate that five definitions of patient flow allow for various improvement techniques to be applied in establishing recommendations to optimize flow and patient throughput in the WAMC ED. These key findings and recommendations include: 1. establishing patient flow within WAMC's strategic vision; 2. conducting hospital-wide patient flow analysis utilizing real-time, patient-centric data; 3. utilizing the ED length of stay (LOS) and ED left without being seen (LWOBS) rate as the key measures to improve ED patient flow; 4. analyzing the ED LOS and LWOBS rate by hour of day and day of the week for impacts on patient flow; 5. developing accurate forecasts on the daily average ED census to optimally align short-term and long-term staffing needs; 6. creating a set of ED queuing models that verify staff and space requirements for triage, registration, and treatment areas; 7. utilizing a set of ratios to identify specifically where WAMC ED capacity is not aligned with patient demand; 8. analyzing the impacts of both laboratory and radiology order cycle times on WAMC ED LOS improvement efforts; 9. evaluating the impacts of performing initial treatment in triage area to increase the service rate of main ED beds; and 10. analyzing the impacts of an ED patient tracking application on increasing the efficiency and effectiveness of WAMC ED staff to care for patients.

15. SUBJECT TERMS
Patient flow, Flow, Throughput, Emergency department, Emergency room, Forecasting, Queuing, Patient demand, Capacity, Patient tracking, Patient-centric, Real-time data

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	112	Education Technician
					19b. TELEPHONE NUMBER *(include area code)* (210) 221-6443

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Graduate Management Project

A case study to improve emergency room patient flow at Womack Army Medical Center

Presented to

Faculty, U.S. Army-Baylor University Graduate Program in Health and Business Administration

& Staff, Womack Army Medical Center, Fort Bragg, North Carolina ('Center of the Universe')

For Completion of Degree Requirements in
Masters of Healthcare and Business Administration (MHA/MBA)
By
MAJ Daniel E. Reynolds
June 2009

Acknowledgements

Several people provided input and support in completing this project. First, LTC (Ret) Jessie L. Tucker III, as my preceptor for over half of my residency, provided excellent guidance and positive critique throughout this project and all related resident ideas. Second, LTC Brian Burlingame, as head physician (DCCS) for most of my residency, convinced me that a project on ED operations was needed more than a project on OR operations. Third, LTC Mark Dole, as my preceptor for the last half of the residency, provided final guidance on the project with a unique perspective on the ED space expansion needs and requirements, as well as a sense of urgency to complete it. Fourth, LTC Kevin Broom, as my Baylor faculty reader, provided clear guidance on how to make this project a cogent set of findings and recommendations. Fifth, Charlene Colon and John Rehder, as clinical informatics specialists, provided the necessary real-time data from CHCS that allowed for the accurate analysis of this project to occur. Sixth, MAJ Cynthia Childress, as another Baylor faculty member, provided advice to attend Institute of Healthcare Improvement courses for free as a student and assigned Operations Management tasks on queuing and forecasting that really helped mold the most significant results of this project. Seventh, Kris Owens and Sonja Crouse, as Moore Regional Hospital's emergency room nursing leadership, allowed me to participate and obtain knowledge on their improvement efforts. Most importantly, Gwen Young, MAJ James Burk, LTC Frank Christopher, Dr. Sean Siler, CPT George Barbee, and SFC Arthur Ebbert, as ED leadership over the last year, provided a realistic perspective that allowed me to truly grasp the challenges of being the front door for Fort Bragg ('Center of the Universe') healthcare. Finally, Amber Reynolds, my wife, afforded me the time to spend reading and writing for all of the Baylor classes and completing this project over the last two years.

Abstract

This graduate project is a case study on how to improve patient flow in the emergency department (ED) at Womack Army Medical Center (WAMC). Results of the case study indicate that five definitions of patient flow allow for various improvement techniques to be applied in establishing recommendations to optimize flow and patient throughput in the WAMC ED. These key findings and recommendations include: 1. establishing patient flow within WAMC's strategic vision; 2. conducting hospital-wide patient flow analysis utilizing real-time, patient-centric data; 3. utilizing the ED length of stay (LOS) and ED left without being seen (LWOBS) rate as the key measures to improve ED patient flow; 4. analyzing the ED LOS and LWOBS rate by hour of day and day of the week for impacts on patient flow; 5. developing accurate forecasts on the daily average ED census to optimally align short-term and long-term staffing needs; 6. creating a set of ED queuing models that verify staff and space requirements for triage, registration, and treatment areas; 7. utilizing a set of ratios to identify specifically where WAMC ED capacity is not aligned with patient demand; 8. analyzing the impacts of both laboratory and radiology order cycle times on WAMC ED LOS improvement efforts; 9. evaluating the impacts of performing initial treatment in triage area to increase the service rate of main ED beds; and 10. analyzing the impacts of an ED patient tracking application on increasing the efficiency and effectiveness of WAMC ED staff to care for patients.

Table of Contents

Introduction

This paper will outline a case study of the Emergency Department (ED) at Womack Army Medical Center (WAMC). As Yin (2003) defines a case study is most appropriate for the exploratory phase of an investigation, but also explains how a case study can be explanatory and descriptive enough to even lead to causal inquiries. The purpose of this case study is to explore all aspects of patient flow at WAMC's ED (i.e. from arrival to triage to registration to treatment and finally to discharge), and begin to determine how patient flow can be improved. Certain key metrics of ED patient flow include the ED length of stay (LOS) as the time it takes from patient registration to discharge, as well as the ED left without being seen (LWOBS) rate or the rate of patients that depart after registration and before treatment is completed (some civilian hospitals term this rate left before treatment complete – LBTC). These key metrics (e.g. LOS & LWOBS) will be divided and analyzed separately in two areas found in the WAMC ED and in many emergency rooms throughout the country. These two areas of the WAMC ED include the main ED of 16 beds currently (2 beds designated for Obstetric patients, 2 beds designated for Orthopedic patients, and 12 all-purpose beds), as well as a Fast Track (FT) area of 12 rooms currently (FT room is similar to an outpatient treatment room of a primary care clinic). The main ED sees all patients who are triaged by Emergency Severity Index (ESI) levels I through III (primarily emergent and urgent patients as labeled in the Composite Health Care System-CHCS), and the FT sees all patients that are triaged ESI levels IV through V (primarily non-urgent patients as labeled in CHCS).

Both the main ED and FT areas are a system of queues that include: 1. Patient arrival to patient seen in triage; 2. Patient complete in triage to patient seen in registration; 3. Patient complete in registration to patient treatment in main ED bed or FT room; and 4. Patient treatment complete to patient discharge home or to a WAMC inpatient ward. These queues will be modeled and ways will be proposed to optimize the efficiency of these internal ED queues to improve patient flow at WAMC's

ED. WAMC's ED patient flow is also affected by many external variables to the ED's internal system of queues and those will be explored in this case study. These external variables include: 1. Main ED bed and space requirements to meet ED census demands; 2. Turnaround time (TAT) of laboratory and radiology testing results; 3. TAT of specialty consults necessary for ED visits and inpatient admissions; and 4. Daily variation of primary care appointment templates and elective surgical schedules. All of these internal ED variables and external WAMC variables may be classified as ways to improve patient flow in not only WAMC's ED, but also perhaps to many other areas of patient flow at WAMC.

Patient flow is best defined by Jensen, Mayer, Welch, and Haraden (2007) into five separate categories to include: 1. Flow as efficiency and cycle times (e.g. TAT on an ED lab order); 2. Flow as reduced variation, increased predictability, & improved forecasting (e.g. less variation in number of inpatient elective surgeries daily allows for staff to meet OR & ED admissions demand more easily, and better forecasting of ED census allows for ED staff to meet patient demands); 3. Flow as systems thinking (e.g. patient flow in the ED is not solely internal to the ED, but improving flow needs to be done at a systems or WAMC level); 4. Flow as empowered providers exceeding expectations (e.g. aligning system incentives to encourage system improvements made at lower levels – incentives for surgeons to smooth out schedules leads to greater throughput, less cancellations, and less delays in surgical care – incentives for ED staff to smooth patient flow and increase patient throughput); 5. Flow as demand capacity management (e.g. forecast ED demands by hour of day, by day of week, and by monthly season to allow for ED staffing and bed capacity to be better aligned with forecasted demand). All of these areas of patient flow will be explored in the case study and used to determine ways to improve patient flow within WAMC's ED as well as proposing additional areas of patient flow improvement within WAMC's health care system.

These areas of patient flow are very important in looking at many of The Joint Commission's (TJC) standards on leadership as the management of patient flow through the hospital is essential to the prevention and mitigation of patient crowding (i.e. a problem that can lead to lapses in patient safety and quality of care, especially in the WAMC ED). In our most recent TJC consultation visit in March 2009, the lead consultant explained that the patient flow system tracer revealed a near complete lacking of patient flow data analysis and stated patient flow analysis is beyond the emergency department and relates to all patient care areas of the hospital (e.g. the impacts that the WAMC OR and inpatient wards have on WAMC's ED). Asplin (2006) calls for a paradigm shift in not measuring ED overcrowding, but focus more positive efforts on measuring patient flow and make improvements off of those measurements. The key metric in ED patient flow is measured through patient throughput, and ED throughput will increase as average ED LOS times decrease and quality of care will be improved as LWOBS rates decrease.

Conditions that prompted the study

The key metrics mentioned earlier for WAMC's ED and many emergency rooms throughout the country include the ED LOS and LWOBS rate. These two metrics are highly correlated, as can be seen by a two-tailed bivariate correlation of the two metrics over the first five months of Fiscal Year (FY) 2009 producing a correlation value of 0.660 (significant at the 0.01 level, all results seen in Appendices A through C). Over the last 3 years or more, WAMC's average monthly LWOBS rate has improved slightly from an average above 10% to an average more currently around 7%. This decrease in LWOBS is actually positive progress considering the ED census continued to increase consistently over the last 3 years (FY07 average daily ED census of 170 to FY08 average of 181 to partial-FY09 average of 187). The increase in ED census is due to not only a 10% growth in active duty population on Fort Bragg from various Army initiatives and continue to increase for similar Army initiatives over the next 3 years, but

also other variables such as access to primary care have impacts on ED census (e.g. shortage of primary care providers). However, the civilian ED benchmark for LWOBS is between 1-2% and the WAMC average of 7% does not include those patients that arrive to the ED and depart prior to patient registration. The WAMC definition of LWOBS is what some civilian emergency rooms term left before treatment complete (LBTC), and these same civilian emergency rooms also calculate LWOBS to be those patients that leave prior to seeing any medical personnel (including the triage nurse). For purposes of this case study, WAMC ED LWOBS are those patients that depart after patient registration and before proper discharge from the WAMC ED by a provider. Patient registration occurs shortly after seeing the triage nurse and discharge from the ED occurs after all treatment is complete.

Better forecasting of ED patient demand may allow for a lower LWOBS rate and better forecasts are possible through various WAMC ED forecasting models. A linear regression forecasting model, with just time in months as the only independent variable, accounted for nearly 57% of the variation (R-squared = 0.57) in average daily ED census, once seasonality is removed using monthly and daily indices. This independent variable of time includes factors such as Fort Bragg's population increase, as well as WAMC's increase in the shortage of primary care providers over the same time period. From this linear regression model, forecasted average ED census can be calculated to within 96-97% of the actual average ED census (i.e. based on a mean absolute percent error (MAPE) score under 3-4% in all cases). A key to accurate forecasting includes the use of monthly and daily indices in combination with the standardized linear regression forecasts or other forecasting models. This forecasting accuracy allows for improvements in 'flow as improved forecasting' and 'flow as demand capacity management' mentioned above by Jensen, et al. (2007). WAMC ED averaged 20 LWOBS patients on Mondays over the last 30 months (Mondays have highest ED census and lowest nursing staff levels), while WAMC ED

averaged 10 LWOBS patients on Fridays over the last 30 months (Fridays have nearly the lowest ED census and highest nursing staff levels).

ED patient registration occurs after ED triage and the queue for ED triage can sometimes last well over 60 minutes during peak patient arrival hours. The wait time for WAMC's ED triage is currently not being calculated, but will be monitored after an electronic queuing system is completely installed (i.e. QMatic currently awaiting final implementation from initial January 2009 installation). The LWOBS rate is also only being monitored across the entire WAMC ED, instead of separately in the main ED and FT areas to determine more specifically where improvements in patient flow may be made to cause a decrease in the LWOBS rate. A high LWOBS rate is certainly a key condition for conducting this study, an improvement of tracking LWOBS in both the main ED and FT areas will be discussed.

The other key metric (ED LOS) is being monitored separately in the main ED and FT areas, and civilian benchmark timeframes are established as follows: 60 minutes for the FT area, 120 minutes for the main ED area on patients discharged home, and 180 minutes for the main ED area on patients admitted to the facility (Jensen, et al., 2007; Welch, Augustine, Camargo, & Reese, 2006; Welch, 2006). Over the first five months of FY09, WAMC's average FT LOS was 164 minutes (over 100 minutes above the benchmark), WAMC's average main ED LOS was over 240 minutes (more than double the benchmark), and WAMC's average ED admission LOS was just under 330 minutes (adding 90 minutes to the ED LOS average for the specialty consult and admission to take place and nearly 150 minutes above the benchmark). Again these timeframes do not include the non-calculated time it takes for a patient to wait for triage and registration in CHCS before the LOS calculation actually begins (i.e. one could easily add 30-60 minutes to all averages stated above). Therefore, these key metrics clearly show the need to study ways to internally and externally improve the patient flow within WAMC's ED and WAMC's patient flow system as a whole. The challenges of a growing Fort Bragg population and

additional pressure to hire enough primary care providers to handle the population growth also dictate needs for conducting this case study.

Another example of how patient flow should be measured in the ED in conjunction with the ED LOS is the relationship with laboratory turnaround times (TAT) or 'flow as efficiency and cycle times' and 'flow as systems thinking' as mentioned above from Jensen, et al (2007). The lab TAT on the weekends is considerably better than during the week (weekend average ED LOS is 218-233 minutes with a higher ED census and average lab TAT of 35-36 minutes, versus weekday average ED LOS is 241-274 minutes with a lower ED census on most weekdays and average lab TAT of 40-42 minutes). Interestingly, the median lab TAT stays the same at 36 minutes for any day of the week. Therefore, the differences in averages really shows the higher number of lab TAT outliers during the weekdays in the lab and agrees with other studies that show lab outliers to significantly increase the average ED LOS (Holland, Smith, & Blick, 2005; Lewandrowski, 2004; Lewandrowski, et al., 2008; Hicks, et al., 2001). This five-to-six minute difference in average lab TAT from the weekend compared to weekday could be a large reason for a lower average ED LOS even with a higher ED census. Overall, the high average ED LOS shows another key condition for conducting this study on improving the patient flow within the WAMC ED and within certain external variables such as the lab TAT.

The future improvement efforts at WAMC also set conditions for this study, and the first of which may be seen in developing a point-of-care testing (POCT) lab capability within the WAMC ED to significantly decrease the average ED LOS (i.e. median time from lab order to arrival in lab for processing is 24 minutes over the first three months of FY09 and could be cut significantly with POCT). Previous attempts to implement a POCT capability at WAMC ED have failed due to difficulties in paperwork required to maintain lab certifications for POCT are too work intensive, but those reasons will be demonstrably eliminated with the WAMC Department of Pathology implementation of a system

called Remote Automated Laboratory System (RALS). RALS is a software data management center from Medical Automation Systems that is being implemented now at WAMC (as of June 2009) and will automate POCT lab paperwork and accounting. Other studies have shown that such software systems are essential to POCT in critical care environments like the WAMC ED (Blick, 2001).

Many opportunities over the next three years outline further conditions for this study. These opportunities include possibly implementing a physician assistant-level (PA) triage system as a WAMC PA demonstrated the 'flow as empowered providers exceeding expectations' as mentioned above by Jensen, et al. (2007). This WAMC ED PA piloted an experimental study on several days within September 2008 and similar efforts have been shown by other civilian emergency rooms to vastly improve in the key metrics (ED LOS and LWOBS) mentioned above (Chan, Killeen, Kelly, & Guss, 2005). This pilot study showed a significant difference in the main ED bed average turnaround time (TAT) from well over 3 hours to just above 2 hours for all patients that were seen in the main ED through the PA-triage system in September 2008. This improvement in main ED bed TAT will be used later in the study with queuing models. The main ED bed queuing model shows a significant increase in main ED capabilities and decrease in main ED LOS, assuming all main ED patients were initially treated in a PA-triage system.

Another opportunity began in early 2009 as the WAMC ED implemented an emergency department patient tracking application (EDPTA) and all main ED/FT patients are input into EDPTA (i.e. using CHCS links) to help track laboratory, radiology, and specialty consult TATs, as well as an enhanced ability to increase ED bed/FT room utilization rates through better real-time patient monitoring. Any improvements sustained due to EDPTA in the laboratory, radiology or specialty consult times and ED bed/FT room utilization rates will be initially analyzed in this case study and need to be further analyzed as EDPTA fully matures. The initiation of a QMatic system in the ED waiting

area mentioned above in January 2009 is still awaiting final implementation. QMatic will give the WAMC ED an ability to monitor the average waiting times to see the triage nurse and adjust triage and registration staffing levels more accordingly to historical patient demands (i.e. by hour of day and day of week). WAMC Department of Logistics facility management staff planned a couple ED expansions in the near future to include an additional seven beds in the next 12 months in the vacated TRICARE area, as well as an additional seven beds in a proposed Radiology storage area in the next 24-36 months. The analysis for these space expansions will be explored in this case study. Further analysis is going to be needed in almost all of these opportunities, as a substantial amount of time (6-12 months) is really needed to diagnose improvements that have been made and further modifications that still need to occur.

Literature Review

As one can expect, the civilian emergency department is very well analyzed in studies and it can become overwhelming to review all of the possible improvements that have been made in patient flow of civilian emergency rooms to compare and contrast for possible improvements in patient flow within WAMC's ED. A good place to start is a conglomeration of results from case studies compiled by the Advisory Board (2008) titled 'The High Performance ED' as it summarizes over 20 best practices found in emergency departments throughout the world and concludes with four overarching lessons. Some of these best practices have already been implemented at WAMC ED (e.g. low-acuity fast track) and others are very supportive of the possible improvements to be made at WAMC ED in the next 2-3 years (e.g. EDPTA to leverage data and technology in patient tracking best practice or PA-triage system as described in expedited triage best practice). Still others confirm future challenges within WAMC's health care system to improve patient flow within the ED (e.g. demand-based staffing model best practice) and within other WAMC departments (e.g. patient placement command center protocol to improve ED inpatient admission time or lab intervention field guide practices to implement POCT

within WAMC ED). The ED best practices are not only overwhelming in evidence, but the evidence is clearly from a national standpoint that the challenges in the ED have gotten worse over the last 10 years (i.e. ED census increasing with decreases in the quantity of emergency rooms nationwide) and will likely continue over the next years (CDC, 2005).

A final conglomerate of patient flow improvements can also be found through the innovative efforts of the Institute of Healthcare Improvement (IHI) results from personal IHI (2003) efforts with many hospitals throughout the country in improving patient flow. These IHI efforts are well-documented by the results of Robert Woods Johnson Foundation (2009) who with the assistance of federal grants produced great strides in expanding patient flow improvement awareness through success stories at many hospitals throughout the country. Many of these patient flow improvements have been focused on improving flow within the ED, using the internal variables discussed earlier (e.g. aligning ED staffing capacity with current ED forecasted demands) and external variables introduced earlier (e.g. decreasing amount of time to admit ED patients to the hospital ward after consulting with specialty physicians and inpatient nursing staff, or reducing the daily variation in inpatient elective surgeries, both shown to allow for significant reductions in average ED LOS). Two-tailed bivariate correlations using the first five months of FY09 CHCS data also support these practices, as the daily average ED LOS was found to significantly correlate (at the 0.01 level) with the daily number of inpatient elective surgeries (correlation coefficient of 0.341) and with the daily number of ED admissions and ED admission LOS (correlation coefficients of 0.330 and 0.294 respectively seen in Appendix C). These significant correlations are not sole justifications for causing variation in the ED LOS, but the results of the correlations agree with the results of many previous ED studies and deserve being explored in this case study.

Many individual articles support these conglomerations of Advisory Board and IHI best practices of patient flow improvements within the ED and hospitals as a whole. Litvak (2005) wrote a chapter on optimizing patient flow by managing its variability in a Joint Commission Resource textbook. Litvak actually was the lead author on several other articles that showcased a method of reducing inpatient elective surgical variation leading to dramatic decreases in hospitals boarding of patients in the ED awaiting admission, diverting ambulances to other emergency rooms, and increasing throughput in the OR with a near elimination of OR cancellations (Litvak, et al., 2005; Litvak & Long, 2000; Litvak, McManus, & Cooper, 2002; Rathlev, et al., 2007). Other similar studies support efforts to reduce variation and its positive effects across the entire healthcare system as well as certain internal ED variables (Noon, Hankins, & Cote, 2003; Kolker, 2008). Many articles were written stemming from the impacts of IHI innovative efforts mentioned earlier, and many of these were directed at synonymous ways to improve patient flow in an ED and throughout the hospital (Wilson & Nguyen, 2004; Haraden & Resar, 2004; Wilson, Siegel, & Williams, 2005).

Many studies show that the quality of care, as rated by the patient satisfaction level of a particular ED encounter, is greatly influenced by successful patient flow and proven to be very important in the effectiveness of that care (Worthington, 2004; Sun, et al., 2000; Boudreaux & O'Hea, 2004; Welch, 2006). Variables such as the ED LOS are very strongly correlated with patient satisfaction levels, and these patient satisfaction levels dictate how well patients follow through with the medical care and recommendations given to them from an ED encounter. These studies also demonstrate methods to reduce the ED LWOBS rate through better communication about the ED queuing status of the waiting room area specifically, and shows the potential positive impacts the WAMC ED could have on the LWOBS rate from better communication with patients in the waiting room after EDPTA and QMatic are fully implemented.

Various studies have used a finite mathematical formula found in queuing theory to highlight when and where ED bottlenecks occur after reaching at or above 80-85% utilization levels on such servers found in the ED as triage nurses, registration clerks, ED beds with appropriate clinical staff, and FT rooms with appropriate clinical staff (McManus, Long, Cooper, & Litvak, 2004; Green, Soares, Giglio, & Green, 2006). These queuing mathematical models will be used later in the study with hourly ED forecasted demands and estimates on service times in triage, registration, main ED treatment, and FT treatment. The queuing models show exactly how many triage nurses, registration clerks, main ED beds, and FT rooms are needed each hour to maintain utilization below 80%, and calculates an estimated length of time it should take to complete each queue involved in the entire ED LOS. Jensen et al. (2007) summarized five overall techniques uses to improve patient flow include: 1. Measuring and reducing variation; 2. Using better forecasting techniques; 3. Aligning forecasted demand with staffing and space capacity; 4. Queuing theory to determine number of servers and service times needed to maintain utilization below 85% to prevent bottlenecks; and 5. Theory of constraints and how well do we anticipate peaks in demand that exceed our capacity and communicate these constraints to our staff and patient populations to manage expectations and provide possible diversions. These techniques will be utilized in providing findings and recommendations later to the problem of improving patient flow within WAMC's ED that will be summarized now.

Statement of the problem

The average daily census at WAMC's ED is too high for the current treatment space allocated (i.e. more main ED beds are necessary with the current WAMC ED census peaks and even more so with the expected WAMC ED census increases from Fort Bragg population growth). The average hourly WAMC ED staffing levels are not completely aligned with WAMC ED patient arrivals by hour of day and day of week (i.e. using queuing models could improve staffing effectiveness) (Green, et al., 2006).

The TATs on key treatment servers within the WAMC ED (e.g. Main ED beds and FT rooms) are not as efficient as possible. These TATs are partially due to inefficiencies outside of the WAMC ED (e.g. cycle time on laboratory/radiology ordering/processing; cycle time on WAMC ED admissions and ED specialty consults; variation in the WAMC inpatient elective surgical schedule). Therefore, the problem of how to improve patient flow in the WAMC ED relies on improving both WAMC ED internal operations (e.g. space allocation and staffing aligned with patient demand), as well as WAMC external patient flow operations (e.g. lab cycle time). These WAMC patient flow improvements will improve care within the WAMC ED and within many other treatment areas of WAMC. Using the five definitions of patient flow and five overall techniques to improve patient flow defined earlier by Jensen et al. (2007), this problem of improving patient flow at WAMC ED will begin to be answered and drive the recommendations for future analysis and studies.

Purpose and research question

The main purpose of this case study is to answer the research question of "How can patient flow improve at Womack Army Medical Center's Emergency Department?" From this main purpose and research question, possible improvements will be documented and justified through data analysis following the five definitions of patient flow and five overall patient flow improvement techniques (Jensen, et al, 2007). The overall key metrics (e.g. ED LOS and LWOBS) will be used to justify and analyze recommended improvements, as well as ensuring any recommended changes are both good for patients and good for WAMC staff. This case study will be designed for both WAMC Command and ED leadership to make decisions on how to improve patient flow specifically in the WAMC ED and recommend future patient flow studies in other areas of WAMC. This case study is focused specifically on the WAMC ED perspective of improving patient flow and other case studies should be completed to make recommendations on how to improve patient flow in WAMC's OR and inpatient wards as well.

Method and Procedures

The three analytical strategies summarized by Yin (2003) for a case study include: 1. Rely on theoretical propositions (e.g. five definitions of patient flow and five improvement techniques); 2. Set up a framework based on rival explanations (e.g. conglomeration of best practices from Advisory Board and IHI will be analyzed for possible implementation or evaluation if already implemented at WAMC ED); and 3. Develop case descriptions (e.g. WAMC ED space and staffing utilization history from WAMC ED staff interviews and data from EDPTA). Under these three analytical strategies are five analytical techniques that are best utilized together to support explanations of a case study and include: 1. Pattern matching or a comparison of actual and predicted values (e.g. longer ED LOS when staff is not well aligned with demand); 2. Explanation building (e.g. bring in Advisory Board and IHI best practices for ED); 3. Time-series analysis (e.g. two sets of data analyzed over similar time periods to diagnose improvements or decrements in ED LOS or LWOBS); 4. Logic models (e.g. ED queuing models set up to support ideal ED staffing and space allocation); 5. Cross-case synthesis (i.e. one completes a case study on more than one ED). Cross-case synthesis will not be utilized since this study focuses on just the WAMC ED.

With the exception of cross-case synthesis, all of the analytical strategies and techniques summarized by Yin (2003) will be utilized to support analysis of this case study as described above and will be further explained below. The author also recommends that reporting of the case study may take several forms and will include: 1. Graduate composition to fulfill academic requirements; 2. Database of Excel spreadsheets for use in replicating or continuing the case study; and 3. Presentations for WAMC Command and ED leadership to make decisions on recommended improvements. This composition will follow the linear-analytic approach as Yin describes, and follows with the analytical strategies and techniques summarized above. Overall, the case study is of significance to WAMC's patient flow

improvements, and it will be complete by analyzing all available ED best practices, considering all alternate perspectives, and displaying sufficient evidence to support any recommendations on how to improve WAMC ED patient flow.

Study design, types and sources of data, and variables

The case study is designed to utilize patient flow data that is as current as available, and therefore the first six months of FY09 (i.e. October 2008 to March 2009) will be used as the timeframe for most data analysis. Certain improvements will be looked at from the first three months of FY09 to the second three months, and other improvements need more time for complete time-series analysis. Certain forecasting methods use over two years of data (e.g. FY07, FY08, and three months of FY09) to best account for changes in seasonality, and certain historical comparisons will utilize changes from similar months in FY07 to FY09 (i.e. historical time-series analysis). Otherwise, the most current WAMC ED data allows for the consistent increases in ED census from WAMC beneficiary population increases and WAMC primary care shortages to be taken into account as much as possible. The main source of data is CHCS encounter data for the WAMC ED that is updated and posted to the WAMC intranet on a bi-weekly basis by Mrs. Charlene Colon. This CHCS data focuses on certain areas like LWOBS in a set of summary pivot tables. Other sources of data include the staffing spreadsheets for ED providers, nurses, medics, and clerks posted to the WAMC intranet by ED leadership, as well as the end-of-day reports posted by the ED clerks used to confirm CHCS data on daily patient arrivals to WAMC ED and those ED patients falling into categories from LWOBS to ESI levels I through V. Another source of data is from data collected by CPT George Barbee during a PA-triage pilot study conducted in September 2008 and gives a possible service time improvement on main ED beds used in the queuing models to follow. A final source of numerical data comes from the WAMC Surgical Scheduling System (S3) data in collecting reports on the number of daily surgeries falling into certain

categories (e.g. inpatient, cancellations, and first case delays). Other historical data was collected from WAMC ED staff and other WAMC staff in relation to historical operational changes made in ED space utilization or other areas like laboratory operations affecting the cycle times in support of the ED. A probable additional source of data will be from the ED patient tracking application (EDPTA) as it will give an increased ability to calculate ED room utilization rates as well as specialty consult cycle times important to improve patient flow even further within WAMC ED. EDPTA was fully implemented in February 2009 and it is unknown whether data will be available prior to final publishing of this study.

The variables upon which this data will be analyzed are from the patient flow perspective of developing averages around the hour of day and day of the week (e.g. on key metrics such as ED LOS and LWOBS). For example, the LWOBS rate is usually calculated and looked at over time on a monthly basis by ED leadership (e.g. WAMC monthly rate above 7% currently with 1-2% benchmark); however, when looking at LWOBS data for the last two years it shows that an average 20 LWOBS occur on Mondays and only 10 LWOBS occur on Fridays. This drives the need for patient flow data analysis by day of the week and better defines patient flows issues at WAMC ED using the five definitions and improvement techniques of patient flow discussed. The data also shows that the average ED LOS is longest at the 1500 hour and perhaps highlights the misalignment of staffing and space capacity with current ED patient arrival demands in the hours leading up to 1500. These variables will be explored in the case study and utilized to provide WAMC ED leadership with staffing benchmarks, spacing needs, and service time goals on repetitive ED tasks that make up the ED LOS (e.g. triage, registration, treatment, consultation, and discharge).

Data analysis techniques

Initial data analysis will look at the key metrics of ED LOS and LWOBS in relation to ED patient arrivals and ED staffing and spacing levels all averaged by the hour of day and day of the week.

From initial data analysis, one may begin to highlight specific areas of data analysis to be completed on such things as laboratory and radiology TATs by hour of day and day of week (split into time it takes the ED to get specimen to lab or patient to radiology, and time it takes lab and radiology to complete testing). Further analysis by day of week will be completed on average inpatient surgeries, surgical cancellations/delays, primary care appointments, ED arrivals by ESI level I through V, and ED admission LOS (see Appendices A through C). Correlations will be calculated on all of the day of week data points to outline probable causal implications to be looked at in further detail of the case study.

There are limitations to the available data to include: 1. No data available by hour of day on ED arrivals by ESI level I through V and this could be utilized to best allocate ED staffing (i.e. CHCS data by hour of day is available where one may assume Emergent = ESI level I; Urgent=ESI Level II to III; Non-Urgent=ESI Level IV to V although this defeats purpose of 5-tiered system); 2. No data available on patient wait times prior to seeing the triage nurse (i.e. possibly available with QMatic on or about July 2009 onward); 3. No data available on amount of patients that depart WAMC ED prior to triage/registration (i.e. possibly available to estimate through QMatic system); 4. No data available on amount of LWOBS in FT versus main ED (i.e. correct data needs to be coded in CHCS in order for data to be collected on ED clerk end-of-day reports); and 5. No data available on main ED bed / FT room utilization rates to determine areas of improvement for specialty bed utilization, efficiency in bed turnovers, and efficiency in bed placement by charge nurses (i.e. data possibly becoming available with 100% EDPTA utilization after 6-month EDPTA pilot study began in February 2009).

Other limitations in the data include the inaccuracy of CHCS time hacks, due to a lack of standardization in processing and registering patients in CHCS. An example of this limitation is with patients arriving at a certain time in CHCS in radiology. The clerk in radiology actively arrive patients in CHCS, even though patients actually arrive in radiology several minutes earlier and wait in a queue to

see the radiology clerk. Another example occurs when the radiologist adjusts the CHCS order on what particular radiology exam is needed, as the CHCS time hack begins over again at zero time expired whenever a new, edited radiology order is initiated. These sorts of inconsistencies make a good portion of CHCS time data inaccurate to use in patient flow analysis and needs to be deleted from CHCS data before calculating any mean or median cycle times. For example from the laboratory and radiology turnaround times (TAT) analysis nearly 10% of all ancillary orders had an order to arrival time of under five minutes, or an arrival to complete time of under 10 minutes, and neither of these circumstances are likely to have happened. Another example of an inaccuracy of the lab date-time analysis occurs because of any lab tests ordered on LWOBS patients (i.e. patients that don't complete the lab test and depart ED before treatment is complete) or duplicate lab tests are placed on the same patient (i.e. patient only completes one lab test). Presently, these unneeded lab tests are not later deleted from CHCS and appear as extreme outliers in the CHCS date-time data. Therefore, these examples show that patient flow analysis is hampered and made much more difficult in using all of the CHCS date-time data for such analysis.

Following the hour of day and day of week data analysis, forecasting techniques will be utilized and analyzed for accuracy in predicting future ED patient demands by day of the week and month of the year. These forecasting techniques include just a naïve forecast (i.e. using previous month's data), moving averages of 2-4 month timeframe forecasts, and a linear regression forecast. All forecasts will use monthly seasonality indices developed from FY07 through FY08 ED CHCS encounter data, all forecasts are above 95% accurate, and all forecasts demonstrate a varying degree of mathematical knowledge to conduct (i.e. naïve forecast being the easiest to linear regression being the hardest). The final major portion of data analysis includes queuing models developed on the three main space constraints of the WAMC ED currently to include: 1. Triage & registration service locations; 2. Main

ED beds; and 3. FT rooms. From these queuing models, benchmarks for service times of each of the three main constraints will be recommended, as well as the ideal number by hour of day and day of week needed to maintain utilization rates below 80-85%. Queuing theory shows within many ED and patient flow case studies, a below 80-85% utilization is recommended to eliminate most possibilities of bottlenecks due to excessive wait times within the various main ED queues (Green et al., 2006). All remaining data analysis returns to simple ratios by hour of day and day of week to determine anything from misalignments in staffing to possible improvements in lab and radiology TATs.

Subjects under study, objects or events measured

The unit of analysis for this case study is the WAMC ED and the majority of the data analyzed includes CHCS patient-level encounter data for the first six months of FY09. Using the most current CHCS ED data best incorporates the current WAMC ED census (i.e. recent Fort Bragg population increases and primary care provider shortages driving consistent WAMC ED census increases). The most current CHCS ED data allows for current TATs associated with the ED LOS (e.g. lab and radiology TATs to average WAMC ED admission LOS) and allows for initial analysis on very recent improvements adopted within the WAMC ED operations (e.g. EDPTA to advanced triage nurse procedures). This timeframe of the first six months of FY09 make the possible recommendations most relevant to the WAMC Command and ED leadership, and allows one to incorporate analysis on ED patient flow improvements made over the previous two years (e.g. pneumatic tube system installed in July 2007 to transport lab specimens from ED to Lab quickly or even initial analysis on EDPTA and space utilization or PA-triage system used to improve triage protocols). In conjunction with analysis on the first six months of FY09 being used for WAMC ED CHCS data, the same timeframe of data was utilized to gather data from WAMC OR operations and the S3 data system. Finally, any data gathered from either EDPTA or QMatic should fall within similar timeframes for further analysis.

Sampling procedures and means of gathering data

The WAMC ED CHCS encounter data is posted bi-weekly (separated by Fiscal Year – FY07 to FY09) to the WAMC intranet (Clinical Operations Data Portal) by Charlene Colon, a WAMC Clinical Informatics data analyst (FY09 DEM Weekly Tracker.xlsx is the most current spreadsheet). The ED CHCS encounter data is downloaded and pivot tables are utilized to array the data as needed by hour of day and day of week, and the values from these pivot tables are copied and pasted into a separate Excel workbook that constitutes the primary case study database (ED Calculations.xlsx) and contains the initial case study data analysis as discussed above. The pivot table data was then used for building the forecasting (ED Forecasting.xlsx) and queuing (ED Queuing.xlsx) models completed and results will be summarized later. The queuing models utilized service times from either actual observations of triage and registration, or from CHCS average encounter data calculations on treatment times in main ED beds or FT rooms.

Other WAMC CHCS data for laboratory and radiology TATs for the first three months of FY09 and the first three months of FY07 were obtained from another WAMC Clinical Informatics data analyst named John Rehder (Update_Rad_Lab_Turn_Around.xlsx and ER_Lab_Rad_ER_Turn_CY06.xlsx). These data spreadsheets contained all laboratory and radiology orders for the specific timeframes and included many lab orders that went unused or were deemed inaccurate within this timeframe. These lab orders were filtered out of any data analysis through filtering a total cycle time between 15 and 480 minutes, as well as a lab order to arrival partial cycle time between 5 and 240 minutes or lab arrival to completion partial cycle time between 10 and 240 minutes.

The WAMC OR Surgical Scheduling System (S3) data was gathered from reports available on the WAMC intranet site after gaining access to the S3 data system from Jon Gerzog, the WAMC OR S3 administrator. The reports accessed included the OR case counts and tallying daily OR case counts

(inpatient without Obstetrics (OB), inpatient with OB, and overall case counts) for the first five months of FY09, as well as the OR cancellations and tallying daily OR cancellations for the first five months of FY09. Lastly, a monthly first case delay report was gathered from Jon Gerzog for the first five months of FY09 and used to tally daily first case delays greater than 15 minutes (i.e. constitutes a significant enough delay to cause a cancellation later in the day or negate any time-space-available cases from being inserted into the OR schedule). This S3 data was used with daily ED CHCS data in correlations (see Appendix C) to establish possible patient flow improvements to make in the WAMC OR that may have positive impacts on both OR and ED operations as has been seen by many IHI case studies (IHI, 2003; Litvak, McManus, & Cooper, 2002; Litvak, 2005).

Validity and Reliability

Ultimately, the quality of a case study is determined on its trustworthiness, credibility, confirmability, and data dependability (Yin, 2003). These qualities may be judged by the following four tests of validity and reliability. As with all data sources, the data and findings for this case study need to be evaluated for construct validity (i.e. multiple, independent sources of evidence being ideal), internal validity (i.e. data shows and confirms causal relationship of data with data from other published studies), external validity (i.e. extent to which a study's findings can be generalized beyond the unit of analysis), and reliability (i.e. demonstration that the study can be repeated and minimize errors or bias introduced in the study). Again, for purposes of this case study it is not important to generalize beyond WAMC ED patient flow operations.

First, the construct and internal validity are tied closely together for this case study. Both tests of validity are strengthened by reviewing the conglomeration of ED best practices from Advisory Board and IHI references. These may be considered multiple and independent sources from each other, and as the findings from the data shows almost all of the studies support similar findings found in the data

analyzed in this case study. Any disagreements in other case studies from the WAMC ED patient flow data analysis really came about due to either a lack of data on WAMC ED patient flow operations, or the data analysis did not support all of the causal findings from the ED best practices published. This certainly makes sense as both of the conglomerations of ED best practices published did not advocate these to be solutions generalized for every ED in the country. The WAMC ED certainly has unique challenges and advantages all the same, and this uniqueness dictates that the data analysis should not agree with all published ED best practices. However, since the data analysis strongly agrees with the major propositions of this case study (e.g. five definitions of patient flow and five overall patient flow improvement techniques), then this case study has more than sufficient construct and internal validity to make strong recommendations on how to improve patient flow operations in the WAMC ED.

As stated earlier, this case study is only focused on improving patient flow operations at the study's unit of analysis (i.e. WAMC ED), and therefore is not concerned with the external validity of the study. Future challenges will include some external validity concerns in applying patient flow data analysis to other areas of WAMC operations to include the OR, inpatient wards, ancillary services, and outpatient appointment templates all having patient flow impacts on the WAMC ED. In certain circumstances, the improvement of patient flow in one area of the hospital will have even more of an impact on another area's specific patient flow challenges. This may be seen in some data analysis where OR operations may be internally improved (e.g. reduce OR cancellations and delays) by reducing the variation in daily inpatient elective surgeries, as well as reducing the average ED LOS or cycle times for inpatient wards admitting patients from both the OR recovery suite and ED.

Finally, the reliability of this study is good in the sense that the study can be repeated. However, as is the case with almost all case studies, there are real-time variables that cannot be eliminated. One such variable in this study are with the WAMC ED staffing levels. ED staffing levels for nurses,

medics, and clerks have improved slightly over the first six months of FY09, and ED staffing levels for providers have deteriorated over this same time period due to an abnormally high amount of deployed ED providers in support of Joint Special Operations Command (JSOC) and US Army Forces Command (FORSCOM). This variable may have significant impact on some of the findings from the data analysis. The reliability of the findings of this case study are best confirmed by ensuring patient flow data analysis becomes an integral part of data analysis at WAMC. This would ensure similar, repetitive patient flow data analysis completed on the most current WAMC ED patient flow data, and would confirm recommendations from this study especially as both WAMC Command and ED leadership change regularly (e.g. every two years).

Findings and Recommendations

The findings and recommendations to be proposed from the analysis of this case study will be structured in support of the five definitions of patient flow and applicable patient flow improvement techniques outlined earlier (Jensen, et al., 2007). In accordance with the case study guidelines posed by Yin (2003), these five definitions and improvement techniques will also be composed utilizing the analytical strategies and techniques documented to show firm causal relationships. Finally, these causal relationships will be used to propose recommendations in this section to both WAMC ED leadership for specific WAMC ED patient flow improvements, and in the future challenges sub-section to follow other WAMC-wide patient flow improvement recommendations will be outlined for future studies on patient flow. The findings and recommendations below will be based on both qualitative and quantitative analysis, and will start with the broader qualitative recommendations and finish with the focused quantitative recommendations.

Finding and recommendation #1: Patient Flow in WAMC Vision (Flow as systems thinking and explanation building analytic technique). The most overarching definition of patient flow is 'flow as

systems thinking' and the realization that improving patient flow in WAMC ED needs to occur both internally within WAMC ED's micro-system, as well as within WAMC's macro-system (e.g. the OR, inpatient wards, cardiac catheterization lab, endoscopic suite, and all other clinical or ancillary operations in WAMC). The reality is that patient flow will only improve when it is embedded in the vision to improve WAMC. So not only must WAMC ED leadership look to improve patient flow through the ED micro-system, but also the WAMC Command leadership must look to improve patient flow in all appropriate WAMC clinical operations. This requires patient flow to become a WAMC strategic initiative and become included within the WAMC strategic plan. A recommendation for inclusion of patient flow within the WAMC strategic plan is to include the actual words 'patient flow' within the WAMC vision statement, and include patient flow improvements as a strategic objective in all WAMC initiatives as applicable. One recommendation made to the WAMC strategic plan in October 2008 was to adjust the WAMC vision from "The Army's Medical Center of Excellence. The choice of America's finest." to something more objectively focused like "Patient-centered interdependent system designed to be the best at getting better in patient flow and quality outcomes." This is certainly one of many options for an adjusted WAMC vision that includes 'patient flow' as an overarching strategic objective at the apex of the WAMC strategic plan.

Finding and recommendation #2: Patient Flow Data Analysts and Information Systems (Flow as systems thinking and explanation building analytic technique). An easy example of how 'patient flow' in the vision statement would be applied at a lower committee level would be in WAMC space utilization and ensuring patient flow improvements occur with the constant WAMC space reallocation decisions that are occurring frequently. Another example would be in WAMC 'patient flow' strategic objectives being measured by organizational data analysts, as clinical departments are going to need specific patient flow data analysis conducted in order to make improvements. Thus, an additional

recommendation would be to refocus some of the organizational data analysts onto 'patient flow' data. This refocusing would probably have to come at the expense of other data analysis being foregone. There is a definite challenge to refocus data analysts towards patient flow data, but based on the March 2009 Joint Commission consultative report showing a near-complete lack of patient flow data, then perhaps this is a signal of change that is needed.

Many of the organizational data analysts are in the WAMC Directorate of Business Operations (DBO), and much of the data analysis in DBO is perhaps too focused on financial and productivity objectives (i.e. provider-centric data analysis). Future data analysis needs to become focused on improving patient flow operations (i.e. patient-centric data analysis), and this will probably still lead to better financial solvency in the future. An example of improving financial solvency could easily be seen by improving WAMC patient flow in the ED, there is a high likelihood that ED LWOBS would lower and WAMC ED productivity would increase. Any increases in productivity are not only financially rewarded in a civilian setting, but has also become financially incentivized in a military setting through the Army Medical Department's performance-based assessment model (PBAM). Both the current and future challenges of improving 'flow as systems thinking' within WAMC rely on the commitment that is made at an organizational-level to improve flow by adopting it into the apex of our strategic plan (e.g. WAMC Vision) and incorporating it into our regularly scheduled organizational data analysis (e.g. WAMC strategic objectives, WAMC business plan, and WAMC monthly productivity reports shifting focus towards 'patient flow' data analysis).

Another important part under this finding and recommendation is the distinct need for information systems that easily give ED leadership the data in order to make timely decisions. An example of an information system that could be easily improved is in the scheduling of the various personnel that work in the ED and being able to easily calculate hour of day and day of week averages.

One needs this sort of information to better align the ED staffing capacity with the forecasted number of patients expected by hour of day and day of the week for that particular month of the year. These information systems may be built within Excel documents and regularly updated using CHCS data as it becomes available on a monthly basis after CHCS audits are complete within 10 days the following month. This type of information system is absolutely vital for ED leadership to make patient flow improvements, and consistently ensure the proper staffing is aligned with the forecasted patient demand. Organizational analysts in DBO could build such an information system (e.g. decision-support dashboard) naturally as patient flow data analysis is performed.

Finding and recommendation #3: WAMC ED LOS analysis (Key metrics involves all flow definitions and pattern matching analytic technique). The WAMC ED LOS involves all of the definitions of flow as outlined by Jensen, et al. (2007). This analysis on ED LOS by hour of day and day of week demonstrates a pattern seen in other ED cases studies on how to improve flow through demand-capacity management. Therefore, the patient flow data analysis to be performed by organizational analysts towards strategic objectives (e.g. findings and recommendations #1 & #2) needs to include ED LOS as one of two key metrics for measuring success. The timeframe for this case study's initial ED LOS analysis is for the first three months of FY09 and will be expanded to contain the first six months of FY09.

The analysis begins in Table 1 below that depicts the average ED LOS and LWOBS by day of week, and it splits the ED LOS out between main ED patients, FT patients, admitted patients, and LWOBS patients. There are several significant trends in Table 1. First, the main ED LOS on Monday (273.57) and main ED census (114.1) are distinctly higher than any other day of the week and clearly demonstrates why nearly double the LWOBS patients occur on Monday (19.77) with an average LWOBS LOS (293.84). An even further comparison emphasizes this point more when looking at the

LWOBS patients on Friday (10.00) with an average LWOBS LOS (206.83). The main ED LOS on Friday (241.57) is the lowest of any weekday and the main ED census (96.5) is the lowest of any day of the week. Now one would assume the main ED staffing levels would be highest on Monday and lowest on Friday, but in fact the opposite is true for the main ED nursing staff over this same time period. Therefore, it is absolutely essential that WAMC ED leadership monitors current ED trends in census and LOS by day of week and staff appropriately. These numbers clearly highlight that the main ED is much more bottlenecked for space probably on Monday versus Friday as well, and space must be allocated for the ED peaks in demand if ED flow is to be improved.

Table 1. ED Length of Stay (LOS) and Left Without Being Seen (LWOBS) analysis by day of week

1st Qtr FY09	Daily Average	Sunday Average	Monday Average	Tuesday Average	Wednesday Average	Thursday Average	Friday Average	Saturday Average
ED & FT LOS	212.25	210.19	229.37	218.1	216.65	210.33	204.11	196.99
ED & FT average census	183.10	199.4	197.2	176.8	177.1	174.8	172.8	183.6
Main ED LOS	***246.79***	***232.9***	***273.57***	260.9	253.43	246.9	***241.57***	***218.24***
Main ED average census	106.69	***113.7***	***114.1***	105.2	106.2	107	***96.5***	***104.1***
FT LOS	163.44	180.06	168.62	155.27	161.5	152.67	156.77	169.2
FT average census	76.41	85.7	83.1	71.6	70.9	67.8	76.3	79.5
LWOBS LOS	253.68	266	***293.84***	252.01	260.2	276.19	***206.83***	220.66
LWOBS average census	13.82	13.15	***19.77***	15.08	14.07	14.38	***10.00***	10.31
Admit LOS	334.25	327.09	326.22	342.1	311.6	335.84	356.88	339.99
Admit average census	11.50	13.15	12.15	12.46	11.71	11.23	11.23	8.54
Emergent Average census	0.26	NOTE: Sample not large enough to split into day of the week averages.						
Urgent Average census	85.00	86.77	91.85	83.92	84.71	82.23	83.62	81.92
Non-urgent Average census	***87.27***	***101.77***	91.31	80.15	81.29	80.38	82.08	***93.92***

Second, the main ED LOS is actually lowest on the weekends (Saturday is 218.24, Sunday is 232.9, and average is 246.79) while the main ED census is near the average for the week on Saturday (104.1) and above average on Sunday (113.7). One area that helps with main ED efficiency on the

weekend may be seen in the average non-urgent census (i.e. those patients who can be seen in the FT) is much higher on the weekends (Saturday is 93.92, Sunday is 101.77, and average is 87.27) than it is the rest of the week. This also points to limited primary care access on the weekends among other things.

The other area that may help with main ED efficiency on the weekends will be seen later in the laboratory order TATs (i.e. turnaround times), as the TATs on the weekends are distinctly lower than on Mondays and nearly every other day of the week. Another area that does not impact the main ED on the weekends is the number of inpatient surgeries seeking admission from the WAMC OR suite. These promising numbers on the weekend for main ED LOS demonstrate that ED patient flow is affected by all areas of the hospital (i.e. confirms the need to make patient flow part of WAMC Vision and overall WAMC strategic data analysis). These weekend stats on ED LOS also confirms that the ED leadership may better forecast how many non-urgent patients show up on particular days of the week, and ensure the FT can handle increased demands on those days. This highlights the importance of looking at this data by day of week and ensuring staff such as FT providers are staffed heavier on Saturday, Sunday, and Monday when the highest non-urgent average census occurs. The reality is Friday, Saturday, and Sunday have heavier FT provider schedules, and shows how adjusting Friday FT provider hours to Monday can improve flow. Finally, current expansions for the ED do not include any additional FT rooms beyond the 12 FT rooms, and based on future patient demands increasing as well as density of provider staffing needs in late afternoon (e.g. going from 2 providers to 3 providers over certain hours) then 16 FT rooms would be ideal.

In Table 2 below, the analysis is best expanded to look at demands by hour of day also. There are several significant trends in Table 2 and support similar trends identified in Table 1. First, the main ED LOS average by hour clearly shows when the main ED is least stressed at 0500 hours with a main ED LOS of 176.79 minutes, as well as when the main ED is most stressed at 1500 hours

with a main ED LOS of 289.16 minutes (i.e. nearly a 2-hour difference and probably is more than a 2-hour difference when ED triage time is added to the average ED LOS). Similar points of stress may be identified in the FT LOS as the FT opens at 0700 hours with a FT LOS of 101.06 minutes, by the time the second FT provider arrives at 1200 hours the FT LOS is up to 167 .85 minutes (i.e. over a 60-minute increase), and the FT is most stressed at 2100 hours with a FT LOS of 201.96

Table 2. ED Length of Stay (LOS) and Left Without Being Seen (LWOBS) analysis by hour of day

Arrival Hour (1st Qtr FY09)	ED & FT LOS	ED & FT Average Census	Main ED LOS	Main ED Average Census	FT LOS	FT Average Census	ED Admits LOS	ED Admits Daily Average	LWOBS LOS	LWOBS Daily Average
0	240.74	5.52	255.59	4.50	175.35	1.02	353.35	0.37	223.48	0.68
1	233.52	3.88	243.46	3.37	167.91	0.51	352.12	0.36	219.73	0.36
2	201.48	2.82	204.97	2.52	171.48	0.29	282.79	0.21	180.26	0.22
3	194.75	3.03	195.70	2.62	188.68	0.41	306.46	0.28	145.92	0.14
4	190.35	2.72	194.55	2.20	172.67	0.52	276.35	0.22	194.43	0.08
5	164.83	3.04	***176.79***	2.29	128.25	0.75	314.53	0.21	136.43	0.09
6	164.09	3.89	200.56	2.37	107.29	1.52	266.66	0.32	137.50	***0.02***
7	151.19	5.58	196.30	2.93	***101.06***	2.64	287.17	0.33	153.40	0.05
8	159.30	8.23	202.58	4.37	110.30	3.86	313.29	0.49	157.57	0.08
9	182.03	10.10	222.61	5.16	139.57	4.93	316.13	0.59	194.15	0.23
10	189.09	10.73	222.66	5.74	150.48	4.99	346.58	0.57	216.65	0.61
11	196.72	10.86	230.49	5.67	159.76	5.18	351.11	0.59	260.62	0.55
12	213.64	10.67	249.90	5.96	***167.85***	4.72	333.34	0.73	284.47	0.90
13	217.96	10.42	264.65	5.46	166.67	4.97	324.94	0.71	299.04	0.74
14	220.54	10.29	265.47	5.65	165.82	4.64	350.11	0.72	268.04	0.84
15	235.37	10.01	***289.16***	5.27	175.52	4.74	367.16	0.66	322.90	***1.09***
16	223.12	9.32	273.17	4.76	170.81	4.55	346.20	0.55	285.08	0.99
17	234.33	10.00	280.86	5.14	185.10	4.86	367.62	0.68	309.88	0.73
18	230.57	9.85	280.71	4.86	181.75	4.99	295.41	0.55	307.79	0.97
19	232.03	9.75	274.41	5.08	186.00	4.67	406.43	0.59	256.73	0.96
20	228.77	9.34	262.05	5.12	188.36	4.22	324.61	0.55	249.91	0.91
21	242.19	9.39	265.51	5.95	***201.96***	3.45	342.94	0.52	257.98	0.96
22	236.48	7.30	264.76	4.89	179.16	2.41	318.91	0.35	219.00	0.73
23	224.39	6.29	247.06	4.79	151.93	1.50	290.82	0.37	227.37	0.91
Totals and Averages	208.65	183.03	***240.17***	106.67	***162.24***	76.36	326.46	11.50	229.51	13.83

minutes. The FT LOS from midnight until 0700 hours (i.e. FT is currently closed) is much higher as FT patients are transferred to the main ED.

In addition, Table 2 shows initial LWOBS analysis by hour of day and confirms that from 0200 until 1000 hours an average sum of 0.91 LWOBS occurs. This clearly agrees with main ED LOS being the lowest during this same time period (176.79 to 204.97 minutes versus the 240.17 average by hour). This demonstrates exactly when the main ED is least stressed from midnight to noon where the average LWOBS is 0.26 patients per hour. The main ED is most stressed from noon to midnight where the average LWOBS is 0.89 patients per hour. This clearly demonstrates the importance of looking at patient flow data by hour of day and ensuring the staffing ratios correlate with the forecasted patient demands (see Appendix E). This is not being done successfully by WAMC ED leadership as the nursing staff ratios are much too high during the least stressed hours in the main ED and much too low during the most stressed hours. Again, this will be further demonstrated in the later finding and recommendation on demand-capacity alignment, but the first step in the process for WAMC ED leadership is monitoring trends in ED LOS and LWOBS by hour of day and day of week as demonstrated by the data in Table 1 and Table 2 above. These tables may be constructed in minutes from the data already made available to WAMC ED leadership on the WAMC intranet by clinical informatics personnel (e.g. Charlene Colon).

Finding and recommendation #4: WAMC ED LWOBS analysis (Key metrics involves all flow definitions and pattern matching analytic technique). The bottom line is that both ED LOS and LWOBS analysis are the key metrics for WAMC's patient flow data analysis that should be consistently performed by WAMC data analysts, so the ED leadership may make real-time decisions on such things as staffing levels. In further support of the previous LWOBS analysis shown above in Table 1 by day of week and Table 2 by hour of day, it is also important to try and delineate how many LWOBS patients

occur from the main ED versus the FT. In CHCS this data is able to be captured by the place of care ('Emergency Room' versus 'Fast Track' in CHCS), and it may also be estimated by the arrival category ('Emergent' and 'Urgent' assumed to be seen in the main ED predominantly, and 'Non-Urgent' assumed to be seen in the FT predominantly). This is demonstrated as Table 3 below depicts most non-urgent patients who completed their appointment (i.e. 'Kept' in CHCS) were seen in the FT and most emergent/urgent patients were seen in the main ED. However, most patients (i.e. nearly 90%) who did not complete their appointment (i.e. 'LWOBS' in CHCS) were not coded in CHCS with an arrival category of emergent, urgent, and non-urgent. Nearly all of the LWOBS patients were coded as being from the main ED, but based on anecdotal evidence from the WAMC ED head nurse there is a significant amount of LWOBS patients from the FT.

Table 3. ED Left Without Being Seen (LWOBS) analysis by ED location (5 months of FY09)

Emergency Dept Location	Appointment Status	Coded Blank in CHCS	Coded Emergency	Coded Non-Urgent	Coded Urgent
Main Emergency Department (ED)	Kept	211	101	2174	***12174***
	LWOBS	***2153***		113	111
Main ED Total		2364	101	2287	12285
Fast Track (FT)	Kept	49		***10901***	803
	LWOBS			2	
FT Total		49		10903	803
Main ED & FT Total Demand		2413	101	13190	13088

This clearly demonstrates a need to better capture the data in CHCS prior to any further data analysis on LWOBS from the main ED versus the FT. The importance of being able to delineate LWOBS is to better adjust the staffing schedule by day of week and hour of day for both the main ED and FT to lower the LWOBS percentage overall to the civilian ED benchmark below 1-2%. The WAMC ED LWOBS percentage from FY06 was well above 10% and the most current WAMC ED LWOBS percentage from FY08 and into FY09 is between 6-8% for a monthly average. There is room

for improvement in LWOBS, and as will be shown by later correlations LWOBS can definitively show by exact hour of day and day of week where staffing and ED space are not sufficient enough to support ED patient demands that may be forecasted to a 95+% accuracy level (as shown in next Finding below).

Finding and recommendation #5: WAMC ED Forecasting models (Flow as improved forecasting and logic model analytic technique). The purpose of the following forecasting models is to determine the forecasting model that will most accurately predict a daily average of ED visits to make both short-term and long-term staffing decisions. Accurate forecasting on a daily basis using daily indices allows for accurate short-term staffing schedules to be published. Long-term staffing requirements are better planned with more accurate forecasts taking into account seasonal variation using monthly indices. The forecasts are evaluated on a mean absolute deviation (MAD) and mean absolute percent error (MAPE) computed for each forecasting technique. Naïve forecasts use just the previous month, moving average 2-month period (MA2) uses the average from the previous two months, moving average 3-month period (MA3) uses the previous three months, moving average 4-month period (MA4) uses the previous four months, and linear regression uses 27 months of ED daily census averages for those months (October 2006 through December 2008). From the first 24 of 27 months, monthly indices were calculated and used to standardize the monthly averages and then recomputed back into the data to make final forecasts for each method. Although not displayed in this section the Emergency Severity Index (ESI) levels I through V were analyzed by day of week and there were no significant differences in percentages of ESI levels on any particular day of the week, nor any month of the year. The ESI levels are currently not captured by hour of day, as CHCS only captures an arrival category of Emergent, Urgent, and Non-urgent with a particular date-time stamp.

Table 4 below depicts the results of the various forecasting models for each month in 2008, and also shows the monthly indices used to produce these forecasts. So, February 2008 has a monthly index

of 1.15 which means that in the month of February the WAMC ED should expect to see 15% more patients in February than the average month throughout the rest of the year. On the other hand, the months of June, July, and August the WAMC ED census should be 4-5% below the average. These indices should be regularly updated with the most current two years worth of data and are absolutely vital in producing accurate ED census forecasts (e.g. 2008 uses FY07-08 indices, 2009 starts to use CY07-08 indices for greater accuracy). In forecasting, the seasonality is first removed by dividing by the monthly index for the month(s) being used in the forecast, the appropriate forecasting technique is applied (from naïve to regression), and then seasonality is finally added back into the forecast by multiplying by the monthly index for the month(s) actually being forecasted. In just perusing the various monthly forecasts of Table 4 below, it is very difficult to determine which technique is the most

Table 4. ED forecasting results 2008 using five different forecasting methods with monthly indices

Month	Actual	FY07-08 Monthly Indices	Naïve	Moving Average (2-month period)	Moving Average (3-month period)	Moving Average (4-month period)	Regression
Jan-08	181.06	1.03	175.66	180.04	181.71	168.78	185.03
Feb-08	218.75	***1.15***	202.94	199.92	202.18	181.55	208.47
Mar-08	186.68	1.04	196.96	189.84	185.66	206.32	188.68
Apr-08	182.47	1.00	179.92	184.87	181.95	185.91	182.78
May-08	183.84	1.01	184.09	182.80	185.70	182.08	185.35
Jun-08	175.47	0.96	174.21	174.32	173.55	185.24	176.53
Jul-08	181.77	***0.95***	174.57	173.95	173.82	174.03	176.53
Aug-08	176.81	0.96	182.67	179.05	177.42	175.81	178.29
Sep-08	192.70	1.02	189.53	192.67	191.13	177.27	192.08
Oct-08	191.48	0.95	178.64	177.17	178.62	191.52	178.95
Nov-08	187.57	0.97	196.02	189.44	186.25	181.84	184.10
Dec-08	182.45	0.97	187.60	191.83	188.86	186.58	185.05

accurate, but it is clearly seen that all of the forecasting techniques with the monthly indices produce a highly accurate forecast (later analysis shows specific accuracy levels).

Table 5 continues the forecasting techniques into 2009, using updated monthly indices from the most current 24 months of data, and displays the absolute error for the first two months where actual CHCS ED data is available. The absolute error values are lowest for the simplest forecasting technique (naïve), and are actually the worst for the most complicated forecasting technique of regression (although time is the only independent variable in the regression equation). Table 5 does show that the WAMC ED leadership should use a variety of forecasting techniques to allow them to make short-term staffing benchmarks (i.e. next 1-3 months using naïve or moving average techniques) and more long-term staffing benchmarks (i.e. next 12-24 months using a regression forecast and possibly incorporating more independent variables than just time). Time has been an

Table 5. ED forecasting results 2009 using five different forecasting methods with monthly indices

Month	Actual	CY07-08 Monthly Indices	Naïve (Error)	Moving Average 2-month (error)	Moving Average 3-month (error)	Moving Average 4-month (error)	Regression (Error)
Jan-09	184.94	1.01	189.98 (5.05)	192.67 (7.73)	196.49 (11.56)	187.25 (4.65)	193.64 (8.70)
Feb-09	204.75	1.14	207.56 (2.81)	210.40 (5.65)	213.35 (8.60)	193.61 (13.48)	218.39 (13.64)
Mar-09	***207.97***	1.02	184.24 ***(23.73)***	185.50	187.62	211.20 ***(3.23)***	197.47
Apr-09		0.99		177.65	178.87	187.62	191.34
May-09		0.99			179.22	178.87	193.96
Jun-09		0.94				179.22	184.73
Jul-09		0.94					184.93
Aug-09		0.94					186.51
Sep-09		1.01					200.99
Oct-09		1.02					202.90
Nov-09		1.02					203.58
Dec-09		0.98					196.99

accurate, independent variable in 2008 due to the increases in patient population on Fort Bragg (Base Realignment and Closure-BRAC and Grow-the-Army initiatives), along with increases in primary care provider shortages steadily causing increases in ED census over time. These same challenges in patient population increases and increasing primary care provider demands will occur over the next 2-3 years on Fort Bragg as well. However, certain months are going to have unexpected changes in ED census, such as March 2009 shown above (207.97 daily average) as the seasonal flu increases appeared more in March 2009 than in February 2009 that was lower than forecasts. Using a variety of forecasting techniques allows one to possibly have a range of ED daily census forecasts from which to make staffing decisions, as Table 5 shows MA4 to be most accurate for March 2009.

Table 6 displays the accuracy of each of the five forecasting techniques for the 23-27 months of forecasts over the FY07-09 timeframe. The MAD for nearly all of the techniques was below six patients, and the MAPE clearly shows even the most inaccurate forecasting model was nearly 95%

Table 6. Accuracy results of various ED forecasting techniques for 2007-2008 by month

	Naïve	Moving Average (2-month period)	Moving Average (3-month period)	Moving Average (4-month period)	Regression
Mean Absolute Deviation (MAD)	5.5996	4.9947	***4.4570***	9.1242	4.8825
Mean Absolute Percent Error (MAPE)	3.15%	2.80%	***2.50%***	***5.11%***	2.75%
Mean Absolute Deviation 2008			***4.4391***		***3.7568***
Mean Absolute Percent Error 2008			***2.38%***		***2.01%***

accurate. Since the MA3 and Regression forecasting techniques were the most accurate, those techniques were evaluated separately using just calendar year 2008 forecasts to show regression as being nearly 98% accurate and MA3 being well over 97% accurate. The accuracy of these monthly forecasts demonstrate a very accurate way for WAMC ED leadership to benchmark long-term staffing needs into the next 12-24 months using a Regression forecast, and possibly confirming these results on a monthly or quarterly basis using a Naïve or MA3 forecast respectively when making more short-term staffing and actual scheduling of available staff. The actual scheduling of available staff should take into account the patient demands by hour of day, but even more importantly it must take into account the variation in patient arrivals by day of the week. The variation in patient arrivals by hour of day usually follows a similar percentage increase or decrease depending upon the variation by day of the week as well as month of the year. Therefore, the final forecasting tool needed by WAMC ED leadership is a tool to accurately forecast the patient demands by day of the week and this is displayed in Table 7 below.

Since the MA3 and Regression forecasts turned out to be the most accurate techniques for monthly forecasts (see Table 6), these two techniques were applied to the daily forecasts (see Table 7). These daily forecasts were focused on the 1st Qtr of FY09, as this simulated when short-term staffing and scheduling decisions would be made by WAMC ED leadership. Table 7 below specifically shows the accuracy of these daily forecasts to be quite good, as all of 2008 was 96-97% accurate. For the most part, Table 7 shows that the accuracy of using separate regression formulas for each day of the week, or an even simpler method of just using the monthly regression formulas along with daily indices, produced very accurate results (94-97% accurate). The most inaccurate day of the week turned out to be Monday as well as Friday for nearly both time periods and

Table 7. Accuracy results of various ED forecasts for 2008 and 1st Qtr FY09 by day of week

Mean Absolute Percent Error (2008)			Mean Absolute Percent Error (1st Qtr FY09)		
Day of Week	Moving Average (3-month period)	Separate Daily Regression Formulas	Day of Week	Separate Daily Regression Formulas	Monthly Regression w/ Daily Indices
Sun	2.62%	2.79%	Sun	5.25%	2.85%
Mon	4.21%	3.31%	Mon	5.58%	5.16%
Tue	2.86%	2.75%	Tue	2.74%	3.51%
Wed	3.66%	3.01%	Wed	4.792%	4.786%
Thu	3.86%	3.33%	Thu	4.50%	4.57%
Fri	4.18%	3.63%	Fri	3.25%	2.51%
Sat	2.63%	2.24%	Sat	2.98%	2.92%

forecasting techniques. This demonstrates there is significant variation in a Monday or Friday ED patient census depending upon if that Monday or Friday falls on a federal or local training holiday (ED census is abnormally lower on holidays). A separate index for holidays could possibly be developed and better account for some of the forecast differences in holidays experienced on any particular day of the week and the day after the holiday may experience abnormal variation as well (e.g. 1st Qtr FY09 had holidays or recovered from several holidays on Wednesday and Thursday as well).

Overall, as a short-range planning tool, ED forecasting techniques offer an ability to better align ED staffing by day of week. As a long-range planning tool, ED forecasts offer this same ability to better align ED staffing by month of the year (e.g. February census usually is distinctly higher in ED, as well as enrollment increasing over last year and shortages in primary care providers increasing over last year leading to a distinct increase in ED census at WAMC, especially in first 3 months of FY09). The most powerful portion of the forecasting techniques is developing and consistently updating the daily indices to use with short-term forecasts and monthly indices to use with long-term forecasts.

Finding and recommendation #6: WAMC ED Queuing models (Flow as reduced variation / increased predictability and logic model analytic technique). The challenge of properly aligning ED capacity with random patient demands includes optimization of staff (e.g. finding #7) and space. In the WAMC ED, there is a shortage of space (e.g. treatment areas) during certain hours of the day and days of the week that causes significant bottlenecks. An accurate way for the WAMC ED to model optimum staff and space requirements together is to use WAMC ED queuing models for the system of queues as previously described (e.g. triage, treatment in ED, treatment in FT, and discharge). In order to build these queuing models, four recent months of WAMC ED CHCS encounter data was obtained for analysis and testing (i.e. first four months of FY09). Hourly averages of patient arrivals were calculated to use as arrival rates in the queuing models, and averages on service rates were calculated from work measurements on triage nurses/registration clerks, as well as averages on actual service rates calculated on both FT rooms and main ED beds separately for the four months of encounter data (i.e. CHCS time from health care provider seen until patient discharge used as FT rooms and main ED bed service time).

The purpose of this section is to determine the ideal number of triage nurses, registration clerks, FT rooms, and main ED beds that need to be available each hour of the day, by day of the week, to maintain utilization rates below 80-85% on all servers. Maintaining this utilization rate will minimize the ED length of stay (LOS), and allow one to propose different server rates during peak & non-peak hours for triage/registration. Different assumptions will also be made on server rates of main ED beds based on previous data available from a physician assistant (PA) triage system developed to do more in triage and thus reduce the service time in a main ED bed. Queuing models were set up for each hour of the day (HOD) by day of the week (DOW). Since there is consistent variation throughout the year by DOW, this breakout serves as sensitivity analysis to the overall queuing models. The DOW breakout of ED queuing models account for the maximum number of servers (e.g. main ED beds) needed to

maintain below 80-85% utilization for any HOD, any DOW, on any particular month of the year. Total arrivals per hour were used for the triage nurses. All emergent/urgent arrivals were averaged for the main ED bed queuing model. Finally, all non-urgent arrivals were averaged for the FT room queuing model. All FT (i.e. non-urgent) arrivals from 0100-0700 hours were placed as ED arrivals, since the FT is closed from 0200-0700 hours. These queuing models allow the ED leadership to make staffing decisions on triage nursing levels as well as registration clerks. These models allow ED leadership to show exactly how many additional beds are needed to support the WAMC Master Facility Plan of ED expansion. Finally, these models benchmark the server rates on all FT rooms and main ED beds necessary to improve the overall ED LOS, lower the LWOBS rate, and support ED census increases in the next few years due to BRAC population increases on Fort Bragg.

The WAMC ED has a rough plan to expand the main ED from 16 beds (2 of which are Ortho and 2 of which are OB/Gyn rooms) to 23 beds, or a gain of 7 additional beds that can fulfill general all-purpose main ED needs. The TRICARE Service Center was moved out of its previous location next to the ED FT in January 2009 and this will allow the FT to move and make space for these 7 additional beds for the main ED. The renovations for the 7 additional beds will begin construction as early as July 2009 and will likely be completed within 90 days from initiation. In this additional space vacated by TRICARE, the queuing models demonstrate an additional need to go from 12 to 16 FT rooms as the FT census continues to rise in the next 2-3 years. This is also due to the FT not currently seeing all of the non-urgent arrivals as shown in the LWOBS analysis above. Based on the queuing models, it appears that 16 FT rooms will provide ED leadership with the capability to expand FT capabilities during the highest FT census hours each day in the late afternoon, as well as almost all weekend daylight hours.

The WAMC clinical leadership believes that this expansion of 7 main ED beds will still not be enough beds and another planned expansion of 7 main ED beds is planned in a Radiology records storage room off of the main ED. There has been no data analysis to show exactly how many beds are needed in the WAMC main ED, and these expansions are very expensive to undertake and will likely lead to permanent staffing increases (at least in nursing levels) that spread out the inefficient ED patient flow problems already occurring. A proposed alternative to another expensive renovation for an additional 7 main ED beds is to improve the utilization of space already allocated to the ED. This recommendation includes utilizing a 4-bed room in the triage area (i.e. originally designed as an air evacuation holding area and currently being used as an ED storage room), along with 1-3 triage rooms (i.e. only utilized for advanced nursing protocol after WAMC main ED is in bed-lock). The purpose of these additional 7 treatment spaces is to see all ESI level III patients from 1000-2200 hours. The benefits of this recommendation include an ED expansion quickly, at minimal cost, and improved patient flow since the 4-bed room and 3 triage rooms are already built in areas ideal for patient flow adjacent to the triage area, main ED beds, and FT rooms.

A related civilian benchmark for the WAMC ED space requirements is to have 1500 annual patient visits in each ED bed/FT room, while in FY08 there were 68,000 visits in 28 beds (16 in main ED and 12 in FT) or about 2429 annual patient visits in each bed/room. Therefore, this ratio clearly demonstrates a need to further research any proposed WAMC ED expansions. The WAMC ED does see a higher amount of non-urgent patients than a normal civilian ED for various reasons, and therefore will always maintain a ratio above 1500 annual patient visits per treatment space. However, the WAMC ED census increased significantly over the last 2 years due to BRAC, Grow-the-Army, and other Army modularity initiatives. These initiatives are expected to continue at least over the next 2-3 years, so the expected ED census will continue to increase, especially if the

primary care provider shortage grows over time as it seems to be as well (i.e. shortage of 15+ primary care providers grew to 20+ over the last 9 months).

The utility of queuing theory does not stop with space requirements. Using queuing theory, the ED leadership can diagnose what needs to occur not only in expanding ED space, but also improving ED patient flow through establishing clear staffing benchmarks and providing the basis for additional staff needed to implement a PA triage system (using the current configuration of three underutilized existing triage rooms). The recommendation above for using these three triage rooms, as well as the air evacuation holding room able to hold 4-beds would allow for an even more robust MD/PA triage system that treats and discharges as close to 100% of the ESI level Category III patients as possible. A scaled-back version of the MD/PA triage system is just a PA triage system that was trial tested by CPT George Barbee in September 2008 utilizing two of the three triage rooms. The data from these trial tests were used to confirm possible improvements if all ESI level I-III patients were routed through a PA triage system.

The PA triage system has the potential to decrease the service time in WAMC main ED beds and thus better account for the volume of ED patients likely to increase even more in the next 2-3 years. The only space renovation that would need to be completed for the MD/PA triage system is to take the storage room and turn it back into its original design of holding 4-main ED beds during peak hours (i.e. 1000-2200 hours). Recent space renovation improvements in February 2009 turned a highly underutilized Pediatrics play area into a registration area that flows very well from the triage desks (i.e. a minor renovation that yielded significant patient flow improvements in the triage/registration area). There is significant variation in patient volume by day of the week (DOW) throughout the year, and thus the queuing models are separated out by each DOW to see when utilization rates are above 85%. This DOW sensitivity analysis is built into each of the ED queuing

models (e.g. triage, main ED, and FT) and allows for any significant patient flow bottlenecks to be identified. The MD/PA triage system could be implemented on all patients initially triaged by a registered nurse (RN) to become a main ED patient (Category I-III of ESI levels, all Category IV-V ESI levels go to FT directly), but then the final treatment could be completed in the soon-to-be ED expansion of 23 beds. This alternative is not recommended as it requires all main ED patients to transition between two ED providers for their treatment, and avoiding transitions allows for much less chance of patient safety errors.

As previously stated, four months of FY09 ED data for WAMC was collected and descriptive analysis on the data shows ironies and improvements that could be made in the ED with just the electronic ED patient tracking application (EDPTA). EDPTA was implemented in pilot-phase in February 2009 and should improve communication, leading to improvements in patient flow (e.g. fill main ED beds faster by clearly showing vacancies and turnover beds faster due to EDPTA's ability to provide visual cues on lab/radiology results being completed in real-time on an automatic 3-minute refresh). EDPTA will likely reduce inefficiencies from poor communication that are probably causing the inaccuracy of the ED queuing models proposed (e.g. forecasted queuing models are estimating lower ED LOS than actual average ED LOS due to probable gross inefficiencies caused by poor communication).

The first inaccuracy is seen in the overall service time of 180 minutes used as the current scenario for a main ED bed, although CHCS time hacks show it to be 138 minutes on average from when the health care provider sees the patient until the patient is discharged. This difference is ironic as the model even with a conservative service time of 180 minutes predicts the time in the system or simulated LOS to be 207 minutes (see the Worst COA ED total in Table 8 below), while the actual LOS on average is 237 minutes. Based on the results of this main ED service time

inaccuracy another one for triage is highlighted, as 237 minutes actual LOS minus 138 minutes actual ED service time equals 99 minutes in Triage/Registration. The queuing model for Triage/Registration predicts this queue should average 15-20 minutes (see Table 8), showing the real inefficiencies in having separate triage and registration queues, as well as poor main ED bed turnover rates adding time (i.e. 80+ minutes) to a patient's total LOS in the ED. The simulated LOS from the queuing model also assumes the initial ED expansion to 23 main ED beds is complete. This combination of improvements tentatively show a *possible 30-minute improvement in the ED LOS* with EDPTA increasing communication, the proposed space expansion increasing capacity, and additional staff to operate the 7 main ED bed expansion from 0900 hours to midnight daily.

Table 8. Summary of assumptions and forecasted times for various ED queuing models

All Days Oct08-Jan09	Best COA ED	Worst COA ED	Alt COA ED
Assumption #1	Triage/Reg = 8 min during peak hours and = 6 min during non-peak hours	Triage/Reg = 8 min during all hours	Triage/Reg = 8 min during peak hours and = 6 min during non-peak hours
Assumption #2	PA Triage is staffed w/2 servers 24/7, ED bed svc time is 2 hours, ED beds = 16	No PA Triage system, ED bed svc time is 3 hours, ED beds = 23	PA Triage is staffed w/1 server from 0100-0800 , ED bed svc time is 2 hours, ED beds = 16
Triage-Reg Time	14.70156194	20.3498	14.70156194
PA Triage Time	26.39968012		40.99772673
Main ED Bed Time	123.1680316	186.6892424	123.1680316
Total Time	164.2692737	207.0390201	178.8673203
Improvement (min)	***42.76974648***	N/A	***28.17169988***

The model does accurately predict differences in simulated LOS by day of the week in most cases, although for some reason the main ED LOS is shorter on Saturday & Sunday with a higher census (i.e. opposite of what is predicted by the queuing models). This is partially true due to better lab turnaround times (TATs) on the weekend versus weekdays when lab orders from other clinics

are competing with ED orders for priority in the lab, as well as a much higher number of non-urgent patients on the weekends. The arrival rates are computed specifically by the actual arrivals seen in the four months of CHCS data, and the server rates were estimated as follows. Work sampling of triage and registration service times were calculated to be on average 8 minutes for triage and 6 minutes for registration, and this was during peak hours where the distractions of having an inundated patient waiting area were highest. Therefore, this is a conservative or possibly inflated estimate of 8 minutes for triage service time and 6 minutes for registration. Follow-up work samplings should be done if triage and registration are combined as recommended. These additional work samplings would allow one to determine if 8 minutes total for both functions is realistic. Samplings with these functions combined are impossible to perform under the current ED patient flow structure that separates triage from registration into two different queues (two queues naturally extends the ED LOS). The implementation of a 24/7 PA triage system would also likely lower the service time of triage closer to 6 minutes (i.e. initial RN triage becomes much simpler), and the triage service time of 6 minutes and registration service time of 5 minutes was estimated from work sampling measurements done during non-peak hours in the ED (i.e. 2200-0700 hours) when the patient waiting area is less inundated with patients waiting for a main ED bed.

The improvements in this queuing model assumes under the 'Best COA ED' (see Table 8) that the triage and registration functions are combined and performed simultaneously. The model assumes both functions are performed together in 8 minutes per patient during peak demand of 0700-2200 hours and 6 minutes per patient during non-peak demand of 2200-0700 hours. 'Worst COA ED' assumes 8 minutes per patient under the same staffing conditions during all hours of the day. The service time for a main ED bed was again estimated at 180 minutes (versus the actual 138 minutes from CHCS), and improves to 120 minutes when a PA triage system is implemented. This

improvement to 120 minutes was taken from actual WAMC pilot study data done in September 2008 by CPT Barbee that showed the actual service time for a main ED bed drop from well over 3 hours, 30 minutes mean or median to just at or under 2 hours mean or median respectively. Therefore, the ED queuing model uses 2 scenarios. The first scenario (labeled under 'Worst COA ED') includes 23 main ED beds versus 16 beds currently available and stays at 3 hours service time. The second scenario is with only 16 beds and go to 2 hours service time with the PA triage system (labeled 'Best COA ED' on tables below). The results for both scenarios are explained later. An 'Alt COA ED' is labeled below by taking the best service time scenario for the triage/registration area, and the worst scenario for staffing the PA triage system at lower levels during the hours of 0100-0800.

The FT queuing model uses a very conservative estimate of 90 minutes per patient for a FT room, while the actual CHCS data shows only a 44-minute time block from when the FT provider sees the patient until discharge time. The same irony above with the main ED is also true in the FT, as the actual LOS for FT patients is 164 minutes while the simulated LOS for the 'Worst COA FT' (see Table 9) patients from the queuing model was only 149 minutes. This irony is best explained by the current inefficiencies in separating triage and registration into two queues, as well as taking too long to get into the FT queue from triage and into a FT room thereafter.

EDPTA has the capability to improve communication and eliminate unnecessary patient transitions. These patient transitions occur now with the current ED hard copy record being passed among triage, FT, and main ED staff, and add significant amounts of time to both the ED and FT LOS respectively. However, EDPTA will only help with certain inefficiencies, and EDPTA benefits will only come after 100% usage by all ED and FT staff involved. So, EDPTA offers a way of filling FT rooms more quickly and turning over patients in FT rooms faster with better

communication and accountability from the triage area into the FT room queue or FT waiting area. In reality, EDPTA is not being used in the FT area very often as of May 2009, and EDPTA still needs some nursing staff jobs redesigned to fully implement its use in collecting patient flow data in the main ED as well.

The FT queuing models follow a similar methodology as the ones seen in the main ED queuing models. Therefore, the 'Best COA FT' (Triage/Registration better service times along with a shift in PA staffing hours), 'Worst COA FT' (Triage/Registration worst service times and no shift in PA staffing hours), and 'Alt COA FT' (Triage/Registration worst service times with a shift in PA staffing hours) are summarized in Table 9. The estimates of service times for triage, registration, main ED beds, and FT rooms were intended to be very conservative to allow for WAMC ED leadership to see the efficiencies that could be realized in combining triage and registration efforts, implementing an MD and/or PA-supervised triage system, and shifting the provider staffing in the FT area towards predictable patient demands by hour of the day and day of the week.

Table 9. Summary of assumptions and forecasted times for various FT queuing models

All Days Oct08-Jan09	Best COA FT	Worst COA FT	Alt COA FT
Assumption #1	Triage/Reg = 8 min during peak hours and = 6 min during non-peak hours	Triage/Reg = 8 min during all hours	Triage/Reg = 8 min during all hours
Assumption #2	FT second PA shift is 9 am - 9 pm, instead of Noon-Midnight	FT second PA shift stays Noon-Midnight	FT second PA shift is 9 am - 9 pm, instead of Noon-Midnight
Triage-Reg Time	14.70156194	20.3498	20.3498
FT Room Time	99.09356232	129.0338506	99.09356232
Total Time	113.7951243	149.3836283	119.44334
Improvement (min)	***35.588504***	N/A	***29.94028824***

The sequence of queues in the main ED currently includes triage nurse, registration clerk, and main ED bed assuming the appropriate staff is available for the main ED bed. In looking at the triage

and registration queuing models, one can plainly see that if these two functions remain separate then the 15-20 minutes it would take to get into the Main ED bed queue would likely take double the time and thus adds 15-20 minutes to the ED LOS unnecessarily. Table 8 and 9 above summarize the assumptions and show that a properly staffed triage and registration area will allow over 5 more minutes to be reduced, *for a possible additional improvement of 20-25 minutes off the ED LOS.* Table 10 below

Table 10. Forecasted triage/registration queuing times for 1 non-peak time & 2 peak-time servers (NOTE: 14.70 total proportion of time below is labeled under Best COA ED in *Table 8*)

Hour	Triage / Register Arrival Rate	Percent of arrivals	Triage / Register Server Rate	Triage / Register Servers	Triage / Register Utilization	Avg time in queue (min)	Avg time in system (min)	Proportion of time (min)
0	5.70	3.06%	***10***	1	56.99%	7.95	13.95	0.43
1	3.80	2.04%	***10***	1	38.05%	3.69	9.69	0.20
2	2.82	1.51%	***10***	1	28.21%	2.36	8.36	0.13
3	3.15	1.69%	***10***	1	31.46%	2.75	8.75	0.15
4	2.76	1.48%	***10***	1	27.64%	2.29	8.29	0.12
5	3.13	1.68%	***10***	1	31.30%	2.73	8.73	0.15
6	3.98	2.14%	***10***	1	39.84%	3.97	9.97	0.21
7	5.78	3.10%	***10***	1	57.80%	8.22	14.22	0.44
8	8.20	4.40%	***7.5***	2	54.69%	3.41	11.41	0.50
9	10.12	5.43%	***7.5***	2	67.48%	6.67	14.67	0.80
10	10.77	5.78%	***7.5***	2	71.80%	8.45	16.45	0.95
11	10.78	5.78%	***7.5***	2	71.85%	8.48	16.48	0.95
12	10.88	5.84%	***7.5***	2	72.50%	8.79	16.79	0.98
13	10.88	5.84%	***7.5***	2	72.50%	8.79	16.79	0.98
14	10.54	5.65%	***7.5***	2	70.23%	7.75	15.75	0.89
15	10.35	5.55%	***7.5***	2	68.99%	7.24	15.24	0.85
16	9.58	5.14%	***7.5***	2	63.85%	5.50	13.50	0.69
17	10.11	5.42%	***7.5***	2	67.37%	6.63	14.63	0.79
18	9.86	5.29%	***7.5***	2	65.74%	6.08	14.08	0.75
19	9.97	5.35%	***7.5***	2	66.45%	6.31	14.31	0.77
20	9.65	5.18%	***7.5***	2	64.33%	5.64	13.64	0.71
21	9.53	5.11%	***7.5***	2	63.52%	5.41	13.41	0.69
22	7.63	4.10%	***10***	1	***76.28%***	18.92	24.92	1.02
23	6.38	3.42%	***10***	1	63.82%	10.57	16.57	0.57
Totals	186.36							14.70

shows by hour of the day how many triage and registration clerks should be staffed by the ED leadership. This forecast by the queuing model allows 1-2 triage nurses to be scheduled proactively by hour of day and rotated by the ED charge nurse (currently triage nurses are assigned to triage area reactively to increases in patient demands by the ED charge nurse). The staffing of registration clerks shows an even balance of clerks throughout the 24 hours of the day, while the queuing models demonstrate a clear need to become more heavily concentrated on certain hours of the day based on Table 10 above (e.g. need for additional clerks from 0800-2200 hours).

Similar circumstances of an even balance of nurses throughout the day are true with the ED nurses, and utilization of the queuing models dictate a need for the ED head nurse to adjust nursing staff benchmarks by hour of the day to best align nursing capacity with patient demands. Additional clerks and nurses were hired in January and February 2009, so now is the appropriate time to adjust nursing and registration staff benchmarks before it gets difficult to make personnel staffing adjustments of union workers. The triage & registration server rate in Table 10 above shows it at 10 patients per hour from 2200-0700 hours (i.e. service time of 6 minutes per patient during non-peak hours as previously mentioned) and 7.5 patients per hour from 0700-2200 (i.e. service time of 8 minutes per patient during peak hours). As Table 10 depicts, there are no hours in the day above 76.28% utilization, and thus bottlenecks are prevented from occurring with these planned staffing models. This is much better than the staffing reactions that occur frequently in the triage and registration area (e.g. one server is utilized too long into peak patient hours, and then 2-3 servers are needed to catch up in the late afternoon to early evening hours). A planned staffing model will also allow the main ED charge nurse to concentrate on main ED bed management during peak patient hours, instead of dealing with staffing levels in the triage and registration area. As stated earlier, each queuing model was repeated with forecasts from each day of the week to serve as sensitivity

analysis on each queue. Sunday and Monday queuing models on the triage and registration show some minor bottlenecks during the peak hours of 0900-1500, and two servers for each triage and registration must be maintained during these peak hours, even if two servers cannot be maintained from 0800-2200 as Table 10 recommends above.

In an effort to demonstrate the positive impacts that a PA triage system could have on the main ED patient flow, one need only to look at the results of the queuing models above. The majority of the overall improvements that could be realized in the main ED LOS are not from an expensive space expansion that would also likely lead to ED staffing increases needing to be sustained. At the beginning of this section Table 8 clearly shows that *25-35 minutes off the main ED LOS are predicted to occur if a PA triage system is implemented on all patients to be seen in the main ED.* This is true based on the PA triage system allowing for parallel treatment of patients to begin well before the patient needs to occupy a main ED bed for final treatment and diagnosis.

The queuing models with a PA triage system assume that the main ED bed service time would go from over three hours to two hours. This is a conservative improvement as an initial PA triage pilot study from September 2008 showed that the main ED bed service time dropped from 3 hours, 49 minutes to 2 hours, 9 minutes on average. However, the pilot study was not staffed robustly enough to do a majority of the arriving patients (i.e. only about 33% of patients arriving over any 8-hour time period). Thus, the whole impact may have not been realized as the average ED LOS did not decrease even though the ED bed turnover time improved by 1 hour, 40 minutes for those patients seen. The space is already available today to implement a more robust MD/PA triage system over 7 treatment spaces (4-bed air evacuation holding area room and 3 triage rooms), but any MD/PA triage system would likely require staffing increases.

At a minimum, the PA triage system with 2-3 triage rooms need at least 1 PA and 1 medic, while a more robust MD/PA triage system utilizing all 7 treatment spaces need at least 1 MD, 1 PA, 1 RN, and 1 medic. The recommendation would be to operate the PA triage system on a 24/7 basis with two triage rooms (i.e. servers) as Table 11 shows below. PA staffing increases are already

Table 11. Forecasted PA triage system queuing times for 2 PA triage servers all 24 hours (NOTE: 26.40 total proportion of time below is included with the Best COA ED in *Table 8*)

Hour	PA Triage Arrival Rate	Percent of arrivals	PA Triage Server Rate	PA Triage Servers	PA Triage Utilization	Avg time in queue (min)	Avg time in system (min)	Proportion of time (min)
0	4.55	3.98%	4	2	56.91%	7.18	22.18	0.88
1	3.80	3.33%	4	2	47.56%	4.38	19.38	0.65
2	2.82	2.47%	4	2	35.26%	2.13	17.13	0.42
3	3.15	2.75%	4	2	39.33%	2.74	17.74	0.49
4	2.76	2.42%	4	2	34.55%	2.03	17.03	0.41
5	3.13	2.74%	4	2	39.13%	2.71	17.71	0.49
6	3.98	3.49%	4	2	49.80%	4.95	19.95	0.70
7	3.12	2.73%	4	2	39.02%	2.69	17.69	0.48
8	4.45	3.89%	4	2	55.59%	6.71	21.71	0.84
9	5.40	4.72%	4	2	67.48%	12.51	27.51	1.30
10	5.88	5.14%	4	2	73.45%	17.39	32.39	1.67
11	5.70	4.99%	4	2	71.23%	15.35	30.35	1.51
12	6.13	5.37%	4	2	***76.57%***	***20.81***	***35.81***	1.92
13	5.95	5.21%	4	2	74.36%	18.31	33.31	1.74
14	5.77	5.05%	4	2	72.14%	16.15	31.15	1.57
15	5.67	4.96%	4	2	70.82%	15.01	30.01	1.49
16	5.09	4.45%	4	2	63.62%	10.19	25.19	1.12
17	5.36	4.69%	4	2	66.97%	12.17	27.17	1.27
18	4.98	4.35%	4	2	62.19%	9.46	24.46	1.07
19	5.38	4.71%	4	2	67.27%	12.37	27.37	1.29
20	5.30	4.64%	4	2	66.26%	11.72	26.72	1.24
21	5.93	5.19%	4	2	74.06%	18.00	33.00	1.71
22	5.12	4.48%	4	2	64.02%	10.41	25.41	1.14
23	4.83	4.23%	4	2	60.37%	8.60	23.60	1.00
Totals	114.25							26.40

occurring to make the FT a 24/7 operation, these additional PA hours would be much better spent on a PA triage system. The more robust MD/PA triage system is not needed on a 24/7 basis, but would maximize efficiency of the main ED during the peak patient demand hours from 1000-2200 hours. This MD/PA triage system would require turning a current storage room back into a 4-bed ESI level III treatment area along with the 3 nursing triage rooms (minimally staffed by shifting 1 MD, 1 PA, 1 RN, & 1 medic to these peak hours from non-peak demand hours for the most part). Perhaps the biggest impact that the MD/PA triage system may offer the WAMC ED leadership is the capability to complete treatment on many ESI level III patients in the FT area, especially as it expands to 16 FT rooms possibly in the near future. Therefore, the MD/PA triage system would add additional treatment spaces for the main ED ESI level III patients, as well as prevent the WAMC main ED from going into bed-lock during the peak patient demand of 1000-2200 hours. This is clearly the best way that the WAMC ED may optimize the utilization of space that it already maintains, and allows the WAMC ED triage area to become much more functional and maximize its utilization.

Sensitivity analysis by day of week on the PA triage system shows that the increased ED census expected on Saturday, Sunday, and Monday from 1000-1500 hours will likely lead to bottlenecks even with the 2 triage rooms acting as servers. These are also the exact days and timeframes that efforts should be concentrated on in utilizing a minimally staffed PA triage system above all other hours of the day and days of the week if additional staffing is not available immediately for such efforts.

Table 12 below shows with the current ED scenario (no PA triage system) that 23 beds are needed from 0900 hours to midnight with a service time of 3 hours per patient (equals 0.33 server rate). Sensitivity analysis shows that even with 23 beds on Sunday and Monday from 0900-1500 hours, there are several hours where bottlenecks will still persist (utilization above 85%), and this is

without the expected increases in ED census that are still expected to occur in the next 2-3 years. Therefore, the only way to truly eliminate the main ED bottlenecks is with reducing the expected service time from over 3 hours to around 2 hours with the implementation of a PA triage system, especially during these peak hours identified above on Sunday and Monday. Table 12 also shows

Table 12. Forecasted main ED bed queuing times for up to 23 peak-time main ED bed servers (NOTE: 186.69 total proportion of time below is included with the Worst COA ED in *Table 8*)

Hour	Main ED Bed Arrival Rate	Percent of arrivals	Main ED Bed Server Rate	Main ED Bed Servers	Main ED Bed Utilization	Avg time in queue (min)	Avg time in system (min)	Proportion of time (min)
0	4.55	3.98%	0.33333	16	***85.13%***	29.00	209.00	8.33
1	3.80	3.33%	0.33333	16	71.34%	5.74	185.74	6.19
2	2.82	2.47%	0.33333	***12***	70.52%	9.69	189.69	4.68
3	3.15	2.75%	0.33333	***12***	78.61%	22.87	202.87	5.59
4	2.76	2.42%	0.33333	***12***	69.10%	8.28	188.28	4.56
5	3.13	2.74%	0.33333	***12***	78.21%	21.94	201.94	5.53
6	3.98	3.49%	0.33333	16	74.68%	8.71	188.71	6.58
7	3.12	2.73%	0.33333	16	58.54%	0.93	180.93	4.94
8	4.45	3.89%	0.33333	16	83.24%	23.55	203.55	7.92
9	5.40	4.72%	0.33333	***23***	70.41%	2.05	182.05	8.60
10	5.88	5.14%	0.33333	***23***	76.66%	5.28	185.28	9.53
11	5.70	4.99%	0.33333	***23***	74.33%	3.76	183.76	9.17
12	6.13	5.37%	0.33333	***23***	***79.92%***	8.32	188.32	10.10
13	5.95	5.21%	0.33333	***23***	77.61%	6.04	186.04	9.69
14	5.77	5.05%	0.33333	***23***	75.28%	4.33	184.33	9.31
15	5.67	4.96%	0.33333	***23***	73.91%	3.53	183.53	9.10
16	5.09	4.45%	0.33333	***23***	66.38%	1.05	181.05	8.06
17	5.36	4.69%	0.33333	***23***	69.88%	1.88	181.88	8.53
18	4.98	4.35%	0.33333	***23***	64.90%	0.81	180.81	7.87
19	5.38	4.71%	0.33333	***23***	70.20%	1.98	181.98	8.57
20	5.30	4.64%	0.33333	***23***	69.14%	1.67	181.67	8.43
21	5.93	5.19%	0.33333	***23***	77.29%	5.78	185.78	9.64
22	5.12	4.48%	0.33333	***23***	66.81%	1.13	181.13	8.12
23	4.83	4.23%	0.33333	***23***	62.99%	0.57	180.57	7.63
Totals	110.08	100.00%						186.68924

that from 0200-0600 hours that the main ED can easily go from 16 beds to 12 beds, and this conserves one RN for that 4-hour shift that may be better utilized during the peak hours of 1000-

1400 hours. With the implementation of a PA triage system, the main ED bed queuing models show how the main ED could easily go from 16 to 11 beds from 0100-0800 hours and providing an ability to shift even more RN hours to the peak hours from 0900-1600. Sensitivity analysis from the ED queuing indicate that on late Saturday, early Sunday hours 16 beds are needed throughout portions of the night, and therefore the main ED should only go to 12 beds from Monday through Friday. As Table 9 showed earlier, there are significant improvements that could be made in the FT queuing model as has been shown to be possible with the main ED queuing models above. The easiest adjustment that WAMC ED leadership should make overall is in the FT area and that is taking the second PA shift from noon to midnight hours and making that shift 0900-2100 hours (i.e. coincides with peak in non-urgent patients from 0800-2000 hours). This shift in PA staffing alone would *likely lower the average FT LOS by 30 minutes with no additional staffing.*

As shown in Table 13 below, the queuing time improves by nearly 30 minutes and clearly shows where the utilization rates are too high from 0900-1200 hours daily. Another related issue in PA staffing in the FT by day of week indicates that the third PA shift is 8 hours on Monday-Thursday and 12 hours on Friday-Sunday. Based on the ED census by day of week and hour of day, this third PA shift of 12 hours should be on Saturday, Sunday, and Monday only and occur from 1400-0200 hours (peak FT demand needs 3 PA's on shift from 1400-1900 hours). This change in the third PA shift in the FT would lower the FT LOS significantly during the peak days and hours that have the highest average FT LOS and FT census above all other days of the week. Finally, indications show this third PA shift is from 1900-0700 on Friday-Sunday currently and expanding to everyday in April 2009 to make the FT a 24/7 operation. Based on the current ED non-urgent census demands there is too much of a concentration from 0800-2000 hours (i.e. more non-urgent patient arrivals than urgent) to justify increasing PA hours without increasing coverage during these peak hours. A concentration of PA hours

during the highest non-urgent demands will likely increase the amount of patients seen in the FT area, while also decreasing the average FT LOS as the queuing models depict above. This inability to see all of the non-urgent patients in the FT area will be expanded upon in the next section on demand-capacity alignment.

Table 13. Comparison of forecasted FT room time before and after a 3-hour shift in PA hours

Hour	FT Room Arrival Rate	FT Room Server Rate	FT Rooms before 3-hr shift	FT Room Utilization before 3-hr shift	Proportion of time before 3-hr shift	FT Rooms after 3-hr shift	FT Room Utilization after 3-hr shift	Proportion of time after 3-hr shift
0	1.15	0.66667	6	28.66%	1.43	6	28.66%	1.43
1	0.00	0.66667	0	0.00%	0.00	0	0.00%	0.00
2	0.00	0.66667	0	0.00%	0.00	0	0.00%	0.00
3	0.00	0.66667	0	0.00%	0.00	0	0.00%	0.00
4	0.00	0.66667	0	0.00%	0.00	0	0.00%	0.00
5	0.00	0.66667	0	0.00%	0.00	0	0.00%	0.00
6	0.00	0.66667	0	0.00%	0.00	0	0.00%	0.00
7	2.66	0.66667	6	66.45%	3.78	6	66.45%	3.78
8	3.76	0.66667	6	***91.21%***	8.74	6	***91.21%***	8.74
9	4.72	0.66667	6	***99.15%***	16.20	12	***59.04%***	5.98
10	4.89	0.66667	6	***99.47%***	17.37	12	***61.18%***	6.22
11	5.08	0.66667	6	***99.68%***	18.58	12	***63.51%***	6.49
12	4.75	0.66667	12	59.35%	6.01	12	59.35%	6.01
13	4.93	0.66667	12	61.58%	6.27	12	61.58%	6.27
14	4.76	0.66667	12	59.55%	6.03	12	59.55%	6.03
15	4.68	0.66667	12	58.54%	5.92	12	58.54%	5.92
16	4.49	0.66667	12	56.10%	5.65	12	56.10%	5.65
17	4.75	0.66667	12	59.35%	6.01	12	59.35%	6.01
18	4.89	0.66667	12	61.08%	6.21	12	61.08%	6.21
19	4.59	0.66667	12	57.32%	5.79	12	57.32%	5.79
20	4.35	0.66667	12	54.37%	5.47	12	54.37%	5.47
21	3.60	0.66667	12	***45.02%***	4.50	6	***88.44%***	7.68
22	2.51	0.66667	12	***31.40%***	3.14	6	***62.80%***	3.46
23	1.55	0.66667	12	***19.41%***	1.94	6	***38.82%***	1.96
Totals	76.28				129.03			99.09

In summary, the triage and registration recommendations for this section include WAMC ED leadership combining the triage and registration areas to make one consolidated queue, as well as renovating an additional triage and registration area in the current registration room and underutilized triage room that sits next to it. This will allow the WAMC ED leadership to ideally staff the triage and registration area with two servers each from 0800-2200 (peak hours assuming 8 minutes per patient) and one server each from 2200-0700 (non-peak hours assuming 6 minutes per patient) shown to be the most effective staffing from the triage and registration queuing models. The two additional triage rooms are underutilized by the triage nurses, since the rooms are not in direct sight of the patient waiting area and need to be in order to meet current ED patient care standards. These two triage rooms along with a storage room designed to hold four main ED beds (i.e. air evacuation holding room by original design) should be utilized to operate a robust MD/PA triage system during peak patient demands from 1000-2200 hours. This system would lower the average LOS in the main ED by 30-45 minutes depending upon the day of the week and is well worth the additional staffing increases. Some of these additional staffing increases may be realized by not extending the FT operation to a 24/7 basis, as well as shifting nursing staff hours from 0200-0700 hours by going down to 12 main ED beds.

Additional RN hours and MD/PA hours are likely to occur with both ED expansions of 7 beds initially and another 7-bed expansion being proposed. These ED expansions are not going to completely eliminate the bottlenecks in the main ED that increase the average ED LOS, without putting an MD/PA triage system into operation. However, the initial 7-bed expansion is overdue and should have been completed prior to initial Fort Bragg active duty and dependent population increases over the last 2-3 years. The initial planned expansion of 7 ED beds to 23 beds total in the main ED should occur as the weekend and Monday queuing models show a current need for 1-4 additional beds even with a fully operational PA triage system. These additional 7 main ED beds are even needed before additional

WAMC population increases leading to ED census increases occur over the next 2-3 years. The follow-on proposed expansion of 7 ED beds to 30 beds total in the main ED should not occur, unless these beds were going to be utilized for enhancing the MD/PA triage system efforts that would further reduce the ED LOS and enhance the existing 23 Main ED bed server rate. However, additional MD/PA triage system beds are shown to already be available in 7 treatment spaces in the triage area, and in an optimal location for patient flow.

The second FT provider should work from 0900-2100 hours and reduce the average FT LOS by nearly 30 minutes with no additional staffing, as well as any additional PA hours in FT third shift should be concentrated on Saturday through Monday (days with much higher FT census and longer FT LOS on weekends especially). The main ED should immediately reduce from 16 to 12 beds from 0200-0600 hours on Monday-Friday and thus reduce by 1 RN during this timeframe and shift these 4 RN nursing hours from 1000-1400 hours when ED census is highest. If a PA triage system is implemented, the Main ED could go down to even 11 beds from 0100-0800 hours everyday and again shift these nursing hours to the PA triage system during the peak hours of 1000-1600. The most realistic way to eliminate the patient flow issues in the main ED is with reducing the expected service time from 3 hours to 2 hours for an ED bed. This has already been shown to be possible (WAMC pilot study by PA named CPT Barbee) through a PA triage system utilizing just two underutilized triage rooms over 8-hour timeframes. A more robust MD/PA triage efficiency for all main ED patients (or treatment of all ESI level III patients) would significantly improve main ED patient flow during 1000-2200 hours in 6-7 treatment spaces total.

Finding and recommendation #7: WAMC ED Demand-Capacity Alignment (Flow as demand-capacity management and time-series analysis). As introduced earlier by both the ED LOS and LWOBS analysis there are definite opportunities to improve the alignment of WAMC ED capacity (in

terms of ED staffing and space) with the current WAMC ED demand (in terms of patient arrivals by hour of day and day of week). The section will demonstrate the need for ED leadership to establish hourly staffing benchmarks for all ED personnel to include providers, nurses, medics, and clerks. These hourly staffing benchmarks will allow optimal alignment of ED staffing and treatment space capacity with forecasted ED patient demands. This alignment is best introduced in Table 14 below. Table 14

Table 14. Comparison of patient arrivals (demand) and ED encounters (capacity) by hour of day (NOTE: ED & FT numbers contain LWOBS, while Urgent & Non-Urgent do not contain LWOBS)

Arrivals by Hour of Day	Urgent Demand	Main ED Capacity	***Main ED Over capacity (+)***	Non-urgent Demand	FT Capacity	***FT Under Capacity (-)***	LWOBS Daily Average
0	2.93	4.50	***1.57***	1.92	1.02	***-0.90***	0.68
1	2.16	3.37	***1.21***	1.39	0.51	***-0.88***	0.36
2	1.74	2.52	***0.78***	0.86	0.29	***-0.57***	0.22
3	1.89	2.62	***0.73***	0.98	0.41	***-0.57***	0.14
4	1.84	2.20	***0.36***	0.85	0.52	***-0.33***	0.08
5	1.77	2.29	***0.52***	1.22	0.75	***-0.47***	0.09
6	2.02	2.37	***0.35***	1.85	1.52	***-0.33***	***0.02***
7	2.55	2.93	***0.38***	2.90	2.64	***-0.26***	0.05
8	3.84	4.37	***0.53***	4.33	3.86	***-0.47***	0.08
9	4.32	5.16	***0.85***	5.49	4.93	***-0.55***	0.23
10	4.48	5.74	***1.26***	5.66	4.99	***-0.67***	0.61
11	4.82	5.67	***0.86***	5.61	5.18	***-0.42***	0.55
12	4.88	5.96	***1.08***	4.99	4.72	***-0.27***	0.90
13	4.77	5.46	***0.68***	5.09	4.97	***-0.12***	0.74
14	4.70	5.65	***0.96***	4.86	4.64	***-0.22***	0.84
15	4.26	5.27	***1.01***	4.95	4.74	***-0.21***	***1.09***
16	4.04	4.76	***0.72***	4.51	4.55	***0.04***	0.99
17	4.42	5.14	***0.72***	5.03	4.86	***-0.17***	0.73
18	4.17	4.86	***0.68***	5.01	4.99	***-0.02***	0.97
19	4.16	5.08	***0.91***	4.92	4.67	***-0.25***	0.96
20	4.03	5.12	***1.09***	4.77	4.22	***-0.55***	0.91
21	4.58	5.95	***1.37***	4.14	3.45	***-0.70***	0.96
22	3.53	4.89	***1.36***	3.35	2.41	***-0.93***	0.73
23	3.09	4.79	***1.71***	2.53	1.50	***-1.03***	0.91
Totals	85.00	106.67	***21.67***	87.21	76.36	***-10.85***	13.83

shows not only the results of misalignment (i.e. LWOBS by hour of day), but also where there may be over capacity in the main ED and under capacity in the FT (assuming only urgent patients are seen in the main ED and only non-urgent patients are seen in the FT). The difficulty in this assumption is that some ESI level III patients are coded as non-urgent in CHCS, but all ESI level I through III patients are mandated to be seen in the main ED based on current WAMC ED protocol. Either way, the LWOBS analysis demonstrated earlier and Table 14 continues to demonstrate above, there is a current need to expand the space in both the main ED and FT to handle more patients. The main ED needs the additional capability during peak hours and expected increases in ED census in next 2-3 years. The FT needs to expand the number of rooms in the FT to 16 from 12. These additional rooms would allow the FT to handle more non-urgent patients and relieve the main ED of any bottlenecks for a bed that occur frequently now during peak hours with trying to handle all ESI level III (some classified as non-urgent in Table 14) workload in the main ED. Table 14 also shows that increasing the FT staff from 0200-0700 will not improve LWOBS as only 0.55 LWOBS patients occur during these hours on a normal day.

Most of the shortages in FT capacity seem to be dictated by not being able to clear out the majority of non-urgent patients in a timely manner, especially during the four hours leading up to the 0200 hours FT closure. This FT leakage of non-urgent patients into the main ED after 0200 hours would best be prevented by ensuring the FT staff remains caught up throughout the day and into the late evening hours. Preventing this leakage will also ensure the main ED can comfortably go down to 12 main ED beds from 0200-0700 hours.

A way to go more in depth on the analysis of aligning patient demands with staffing and space capacities, it is best to look at the staffing and spacing ratios by day of the week and hour of the day. Ideally, the staffing (i.e. patients to particular staff members) and spacing (i.e. patients and staff to either ED bed or FT room) ratios should be about the same for each day of the week and each hour of the day.

Therefore, differences in the ratios can be used to see when the ratio is under capacity (i.e. above daily average) or over capacity (i.e. below daily average). These ratios may also show possible causes for increases in the ED LOS and LWOBS rate through 2-tailed bivariate correlations of the staffing and space ratios with the two key ED metrics. As will be seen by some of the correlation results the key metrics have significant positive correlations by day of the week (see Appendix B), but only the ED LWOBS metric has significant positive correlations by hour of day (see Appendix A). This is easily explained by the fact that the ED LOS is dependent upon the staffing ratios not only on that particular hour of the day, but also the ED LOS is sensitive to the staffing ratios on several hours leading up to particular hours of day. An example of this is the ED LOS is highest on the 1500 hour, but the staffing ratio is not the worst on the 1500 hour (really a combination of the staffing and space ratios from the previous several hours caused the ED LOS to peak at 1500 hours). However, the ED LWOBS rate is very sensitive to staffing ratio mismatches on the exact hours that these mismatches occur, as the ED LWOBS rate is highest on the 1500 hour with a 1.09 daily average. In an effort to also show if there have been any recent improvements or decrements in WAMC ED staffing, the analysis that follows is split between the 1st and 2nd quarters of FY09.

Table 15 begins the staffing ratio analysis with the ED nurses by day of week, and overall improvements in nursing staff have been made from 1st to 2nd quarter of FY09 (i.e. five nurses were hired in January 2009). From the nursing staff ratio, the staffing on Monday is consistently under capacity (1.14 ratio in 1st Qtr versus 0.99 average, and 1.03 ratio in 2nd Qtr versus 0.92 average) and staffing on Friday is consistently over capacity (0.89 ratio in 1st Qtr versus 0.99 average, and 0.88 ratio in 2nd Qtr versus 0.92 average). This under staffing on Monday corresponds to a much higher ED LWOBS count on Monday (i.e. nearly 20) versus the over staffing on Friday corresponds to a much lower ED LWOBS count (i.e. nearly 10). The staffing ratio for nurses is more consistent in 2nd Qtr

Table 15. ED patients to nursing staff ratio by day of week (separated by 1st & 2nd Qtr FY09)

1st Qtr FY09	Daily Average	Sunday Average	Monday Average	Tuesday Average	Wednesday Average	Thursday Average	Friday Average	Saturday Average
0700-1100	7.22	6.42	6.93	7.32	7.77	7.93	7.60	6.58
1100-1500	9.22	8.85	8.88	9.18	9.28	9.22	10.20	9.12
1500-1900	8.24	8.43	8.12	8.18	8.32	7.77	7.93	8.92
1900-2300	8.39	8.62	7.85	8.17	8.17	7.97	9.18	8.72
2300-0300	7.22	7.17	6.83	7.00	7.17	7.50	7.60	7.27
0300-0700	6.85	6.77	6.43	6.70	6.82	6.90	7.38	6.85
ED Patients	186.86	202.13	205.33	180.83	180.53	176.83	177.47	186.67
Total Nurse Hours	188.55	185.00	180.20	186.20	190.07	189.13	199.60	189.80
Ratio	***0.99***	1.09	***1.14***	0.97	0.95	0.93	***0.89***	0.98
2nd Qtr FY09	**Daily Average**	**Sunday Average**	**Monday Average**	**Tuesday Average**	**Wednesday Average**	**Thursday Average**	**Friday Average**	**Saturday Average**
0700-1100	7.85	8.08	8.20	7.98	7.58	7.25	7.72	8.13
1100-1500	9.73	10.27	9.65	9.95	9.58	9.00	9.47	10.23
1500-1900	9.29	9.90	9.47	9.32	9.17	8.27	8.97	9.93
1900-2300	8.87	9.00	8.38	8.53	9.00	8.22	9.73	9.32
2300-0300	8.60	8.28	8.80	8.27	9.00	8.98	8.65	8.27
0300-0700	8.44	8.20	8.58	7.97	8.83	8.62	8.65	8.27
ED Patients	193.61	197.63	218.50	190.13	195.25	174.75	186.73	195.00
Total Nurse Hours	211.19	214.93	212.33	208.07	212.67	201.33	212.73	216.60
Ratio	***0.92***	0.92	***1.03***	0.91	0.92	0.87	***0.88***	0.90

FY09 and that is a good trend. As depicted by Table 15 above, the nursing schedule calculates how many nurses are working on six 4-hour shifts that make up the 24-hours in a day. These 4-hour shifts correspond well to most of the other shifts for medics (i.e. medic shifts are either 0700-1900 or 1900-0700 hours) and many of the provider shifts coincide with these 4-hour shifts. There are some challenges in using 4-hour time blocks to publish nursing staff benchmarks for which to strive, and that becomes an issue when patient arrivals drastically change inside of these 4-hour time blocks (e.g. during 0700-1100 timeframe, 60% of patient arrivals occur from 0900-1100). This really prevents the nursing

staff ratio from maintaining consistent levels (e.g. staff is best aligned with hourly patient arrivals) for either the day of the week, or the hour of the day as shown in Table 15.

The nursing staff ratios are perhaps the most important to align with patient arrivals, as the nurses directly impact patient flow throughout the ED, much more than other ED staff members. Therefore, a recommendation is to at least establish benchmarks following these 4-hour time blocks that are aligned with the patient arrival demands in those same 4-hour time blocks. An example of this would be 10 nurses (versus 7.85 average) from 0700-1100, 11 nurses (versus 9.73 average) from 1100-1500, 10 nurses (versus 9.29 average) from 1500-1900, 10 nurses (versus 8.87 average) from 1900-2300, 5 nurses (versus 8.60 average) from 2300-0300 and 4 nurses (versus 8.44 average) from 0300-0700. These benchmarks would lower the average nursing hours from a current average of 211.19 to 200 (i.e. ensures these benchmarks are possible), and would drastically improve the consistency of the nurse staffing ratio throughout the day. An even better solution would be to calculate the nursing schedule in 2-hour or 3-hour time blocks that would not be much more difficult, but add the flexibility to best respond by hour of day to the nursing demands dictated by patient arrivals. In order to establish the smaller nursing benchmarks from 2300-0700, there cannot be a backlog of patients from the evening hours that is likely caused by shortages in staffing and space constraints during the late evening hours presently. There also needs to be an agreement that the main ED will go from 16 beds down to at least 12 beds during this timeframe, as some of the queuing models predicted would be possible in the previous section.

Similar challenges are seen with other ED staff, such as the registration clerks shown in Table 16 below. On a positive note, the registration clerks are better aligned on Monday, but are significantly understaffed on Saturday and Sunday and slightly overstaffed from Tuesday through Friday for the most

part. On another positive note, there has been another couple of clerks hired very recently and completed orientation and training in 2nd Qtr FY09 (i.e. staffing levels will increase in 3rd Qtr FY09).

Table 16. ED patients to registration clerk ratio by day of week (separated by 1st & 2nd Qtr FY09)

1st Qtr FY09	Daily Average	Sunday Average	Monday Average	Tuesday Average	Wednesday Average	Thursday Average	Friday Average	Saturday Average
0700-1530	***3.39***	3.28	3.65	3.40	3.28	3.48	3.42	3.21
1500-2330	***3.49***	3.35	3.83	3.58	3.48	3.41	3.61	3.17
2300-0730	***3.35***	3.19	3.60	3.33	3.36	3.49	3.34	3.08
ED Patients	186.86	202.13	205.33	180.83	180.53	176.83	177.47	186.67
Total Clerk Hours	81.85	78.60	88.60	82.47	80.97	83.01	82.93	75.67
Ratio	2.28	2.57	2.32	2.19	2.23	2.13	2.14	2.47
2nd Qtr FY09	**Daily Average**	**Sunday Average**	**Monday Average**	**Tuesday Average**	**Wednesday Average**	**Thursday Average**	**Friday Average**	**Saturday Average**
0700-1530	***3.56***	3.38	3.88	3.44	3.31	3.94	3.61	3.34
1500-2330	***3.59***	3.13	3.94	3.69	3.56	3.73	3.65	3.40
2300-0730	***3.28***	3.00	3.56	3.38	3.06	3.20	3.58	3.23
ED Patients	193.61	197.63	218.50	190.13	195.25	174.75	186.73	195.00
Total Clerk Hours	83.48	76.00	91.00	84.00	79.50	86.90	86.70	79.70
Ratio	2.32	2.60	2.40	2.26	2.46	2.01	2.15	2.45

However, as Table 16 shows the staffing levels throughout the three different shifts are pretty much even and ED leadership currently strives to staff four registration clerks on each of the three 8-hour shifts. This does not align well with how patient arrivals occur throughout the day, and the impact of too few or too many registration clerks is not easily seen within the ED LOS metric. The ED LOS stopwatch does not start until one of the primary jobs of the registration clerk is completed in registering patients after completion of triage, and a patient cannot be an LWOBS until registered in CHCS by the clerk. The impact of too many clerks or not enough clerks is difficult to quantify by either of the key ED metrics, although registration clerks are very important in placing lab orders in CHCS for the

providers and could be instrumental in updating EDPTA with where patients are assigned to a FT room or main ED bed. Therefore, it is still important to benchmark the levels of registration clerks and possibly create swing shifts in between the three current shifts (swing shifts from 1100-1930 hours and from 1900-0330 respectively) for one clerk a day during the hours of heaviest patient arrivals. An example of benchmarks for registration clerks with these swing shifts would equate to 4 clerks (versus 3.56 average) from 0700-1530, 4.5 clerks (versus 3.59 average) from 1500-2330, and 2.5 clerks (versus 3.28 average). These benchmarks are now currently reachable with the additional registration clerks hired and trained in 2nd Qtr FY09.

The medics' staffing schedule averages are depicted in Table 17 below and again demonstrate similar challenges to the nurses and registration clerks in aligning their schedules better with current patient demands. One difference with the medics is the personnel strength of medics dropped significantly in the 2nd Qtr FY09, but has since recovered in the 3rd Qtr of FY09 to the same levels depicted in the 1st Qtr FY09 of Table 17. The medic staffing benchmarks currently are just to have four

Table 17. ED patients to medic staffing ratio by day of week (separated by 1st & 2nd Qtr FY09)

1st Qtr FY09	Daily Average	Sunday Average	Monday Average	Tuesday Average	Wednesday Average	Thursday Average	Friday Average	Saturday Average
0700-1900	3.97	4.07	3.88	3.97	4.00	3.88	4.02	3.82
1900-0700	3.84	3.90	3.73	3.73	4.07	3.97	3.68	3.58
ED Patients	186.86	202.13	205.33	180.83	180.53	176.83	177.47	186.67
Total Medic Hrs	93.66	95.60	91.40	92.40	96.80	94.20	92.40	88.80
Ratio	2.00	2.11	***2.25***	1.96	1.87	***1.88***	1.92	2.10
2nd Qtr FY09	**Daily Average**	**Sunday Average**	**Monday Average**	**Tuesday Average**	**Wednesday Average**	**Thursday Average**	**Friday Average**	**Saturday Average**
0700-1900	3.44	3.35	3.58	3.57	3.25	3.42	3.47	3.40
1900-0700	3.39	3.35	3.33	3.33	3.42	3.40	3.48	3.47
ED Patients	193.61	197.63	218.50	190.13	195.25	174.75	186.73	195.00
Total Medic Hrs	81.95	80.40	83.00	82.80	80.00	81.80	83.40	82.40
Ratio	2.36	2.46	***2.63***	2.30	2.44	***2.14***	2.24	2.37

medics on each shift, and this does not align with the current patient demands (e.g. 64% of patient arrivals during day shift and 36% of patient arrivals during night shift). Therefore, it is easy to see how the medic staffing benchmarks should be five medics on the day shift and three medics on the night shift (equates to 63% medic staffing on day shift and 37% medic staffing on night shift). This recommendation was given to the non-commissioned officer for the WAMC ED and the reason for the current benchmarks allow for each shift to be staffed by one squad of medics that allows for nearly four medics each shift.

Finally, the provider staffing is perhaps most sensitive as it is clearly the most expensive portion of WAMC ED personnel costs with many deployments of WAMC military ED providers necessitating expensive personnel contracts for ED physicians and physician assistants. The WAMC ED chief handles the provider scheduling using an online based system called WebSked, and since the data for provider scheduling was not readily available on various Excel spreadsheets only one month of data was tabulated (i.e. January 2009 a recent month and contained an average number of deployed WAMC ED providers at three providers total). It is important to note that, in the summer of 2009, as many as 6 WAMC ED providers will be deployed, including the former WAMC ED chief starting in April 2009. Since the WAMC ED chief is deployed a replacement has been named and will be moved to take the leadership position on 1 May 2009 from another unit on Fort Bragg. Table 18 below shows the average provider staffing of just the Main ED providers by hour of day and day of week, while Table 19 shows the average provider staffing for both the Main ED and FT areas by hour of day and day of week. The totals for the day of week listed in Table 18 show that in January 2009 the provider staffing was lowest on Monday and this happens to be the highest Main ED patient census day of the week (e.g. the staffing ratio is 1.65 and well above the average 1.46). The provider staffing was the most overstaffed

Table 18. Main ED average provider staffing by hour of day and day of week (only Jan 2009)

Main ED only Jan 2009	Daily Average	Sunday Average	Monday Average	Tuesday Average	Wednesday Average	Thursday Average	Friday Average	Saturday Average
0	2.03	2.00	2.00	2.00	2.25	2.00	2.00	2.00
1	2.03	2.00	2.00	2.00	2.25	2.00	2.00	2.00
2	2.03	2.00	2.00	2.00	2.25	2.00	2.00	2.00
3	2.03	2.00	2.00	2.00	2.25	2.00	2.00	2.00
4	2.03	2.00	2.00	2.00	2.25	2.00	2.00	2.00
5	2.03	2.00	2.00	2.00	2.25	2.00	2.00	2.00
6	2.03	2.00	2.00	2.00	2.25	2.00	2.00	2.00
7	2.06	2.00	2.00	2.00	2.00	2.20	2.20	2.00
8	2.06	2.00	2.00	2.00	2.00	2.20	2.20	2.00
9	2.06	2.00	2.00	2.00	2.00	2.20	2.20	2.00
10	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
11	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
12	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
13	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
14	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
15	***4.74***	4.75	4.50	4.75	5.00	4.80	4.60	4.80
16	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
17	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
18	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
19	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
20	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
21	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
22	***3.71***	3.75	3.50	4.00	4.00	3.60	3.40	3.80
23	***3.71***	3.75	3.50	4.00	4.00	3.60	3.40	3.80
Total provider hours	66.10	65.25	64.50	65.75	69.25	66.60	66.00	65.40
Total ED patients	96.26	96.75	106.5	90.5	100.25	88.2	95.8	95.8
Ratio	***1.46***	1.48	***1.65***	1.38	1.45	***1.32***	1.45	1.46

on Thursday according to a 1.32 ratio in Table 18, but this appears to be mostly due to an abnormally low Main ED patient census on Thursdays in January 2009 and could not have been predicted. From this day of week analysis, the only recommendation is to ensure that Mondays gain a higher

Table 19. All ED and FT patients to provider ratio by hour of day and day of week (only Jan 2009)

ED & FT Jan 2009	Daily Average	Sunday Average	Monday Average	Tuesday Average	Wednesday Average	Thursday Average	Friday Average	Saturday Average
0	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
1	3.03	3.00	3.00	3.00	3.25	3.00	3.00	3.00
2	2.45	3.00	3.00	2.00	2.25	2.00	2.00	3.00
3	2.45	3.00	3.00	2.00	2.25	2.00	2.00	3.00
4	2.45	3.00	3.00	2.00	2.25	2.00	2.00	3.00
5	2.45	3.00	3.00	2.00	2.25	2.00	2.00	3.00
6	2.45	3.00	3.00	2.00	2.25	2.00	2.00	3.00
7	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
8	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
9	3.06	3.00	3.00	3.00	3.00	3.20	3.20	3.00
10	4.06	4.00	4.00	4.00	4.00	4.20	4.20	4.00
11	4.06	4.00	4.00	4.00	4.00	4.20	4.20	4.00
12	5.06	5.00	5.00	5.00	5.00	5.20	5.20	5.00
13	5.06	5.00	5.00	5.00	5.00	5.20	5.20	5.00
14	5.06	5.00	5.00	5.00	5.00	5.20	5.20	5.00
15	***6.74***	6.75	6.50	6.75	7.00	6.80	6.60	6.80
16	5.03	5.00	5.00	5.00	5.25	5.00	5.00	5.00
17	5.03	5.00	5.00	5.00	5.25	5.00	5.00	5.00
18	5.58	5.00	6.00	6.00	6.25	6.00	5.00	5.00
19	5.03	5.00	5.00	5.00	5.25	5.00	5.00	5.00
20	5.03	5.00	5.00	5.00	5.25	5.00	5.00	5.00
21	5.03	5.00	5.00	5.00	5.25	5.00	5.00	5.00
22	***5.71***	5.75	5.50	6.00	6.00	5.60	5.40	5.80
23	***5.71***	5.75	5.50	6.00	6.00	5.60	5.40	5.80
Total provider hours	99.74	101.25	101.50	97.75	101.25	98.60	97.00	101.40
Total ED patients	171.56	179.25	193	160.5	171.75	145.4	169	182
Ratio	***1.72***	1.77	***1.90***	1.64	1.70	***1.47***	1.74	1.79

priority in provider staffing by day of week. Table 19 above includes the FT provider staffing and FT patients, and confirms this recommendation of ensuring that provider staffing on Mondays gain a higher priority (1.90 ratio in comparison to an average 1.72 ratio).

This provider analysis also looks at each hour of the day, Table 18 depicts that the additional staffing on Wednesday is really during the hours of lowest patient demand (e.g. more provider night shifts from 1900-0700 hours show these provider staffing hours to be above average while a below average patient census during these hours was shown to be true earlier, only 36% of patients arrive in these 12 hours). The patient demands for the main ED dictate that only two providers are needed from midnight to 0700 hours, and any additional provider hours during this timeframe should be shifted towards late morning hours predominantly. Table 19 confirms this same trend of overstaffing the late night hours slightly when adding the FT provider staffing and shows unnecessary, additional FT provider staffing from 1900-0700 hours for Friday, Saturday, and Sunday. The patient demands dictate that these additional FT provider hours would be better spent on a 1500-0300 hours shift on Saturday, Sunday, and Monday where the FT LOS are highest in accordance with the higher FT patient census demands. WAMC ED leadership is implementing a 24/7 FT schedule now, while the patient demands for the FT are nearly nothing from 0200-0700 hours. The additional FT provider hours would be best spent by changing the third FT provider from an 1800-0200 hours shift, towards a 1500-0300 hours shift while also shifting the second FT provider from a noon-midnight shift, to either a 1000-2200 hours shift, or possibly a 0900-2100 hours based on current FT patient demands by hour of day. This shift in the FT provider hours and ensuring the main ED only goes to 2 main ED providers from midnight to 0700 hours are the only recommendations for better benchmarks of the provider staff with the current WAMC ED patient census demands.

An even more refined way to look at all of the staffing ratios by hour of day to see when overstaffing (i.e. low ratio) and understaffing (i.e. high ratio) occurs is displayed in Table 20 below. This is done by combining the patient arrivals by hour of day for both the 1st and 2nd quarters of FY09. Table 20 begins to clearly show how all of the various staff are overstaffed (i.e. below average ratios)

Table 20. ED patients to various ED staff ratio by hour of day (combines 1st and 2nd Qtr FY09)

1st/2nd Qtr FY09	# Patients	# Providers	Patient / provider ratio	# Nurses	Patient / Nurse ratio	# Medics	Patient / Medic ratio	# Clerks	Patient / Clerk ratio
0	5.63	3.03	1.86	7.91	0.71	3.61	1.56	3.32	1.70
1	3.84	3.03	1.26	7.91	0.48	3.61	1.06	3.32	1.16
2	2.79	2.45	***1.14***	7.91	***0.35***	3.61	***0.77***	3.32	***0.84***
3	3.13	2.45	1.27	7.64	0.41	3.61	0.86	3.32	0.94
4	2.79	2.45	***1.14***	7.64	***0.36***	3.61	***0.77***	3.32	***0.84***
5	3.18	2.45	1.30	7.64	0.42	3.61	0.88	3.32	0.96
6	4.18	2.45	1.71	7.64	0.55	3.61	1.16	3.32	1.26
7	6.03	3.06	1.97	7.54	0.80	3.70	1.63	3.48	1.73
8	8.49	3.06	2.77	7.54	1.13	3.70	2.29	3.48	2.44
9	10.28	3.06	***3.35***	7.54	1.36	3.70	2.77	3.48	2.95
10	10.99	4.06	2.70	7.54	***1.46***	3.70	***2.97***	3.48	***3.16***
11	10.93	4.06	2.69	9.48	1.15	3.70	***2.95***	3.48	***3.14***
12	11.10	5.06	2.19	9.48	1.17	3.70	***3.00***	3.48	***3.19***
13	11.07	5.06	2.18	9.48	1.17	3.70	***2.99***	3.48	***3.18***
14	10.59	5.06	2.09	9.48	1.12	3.70	2.86	3.48	3.04
15	10.29	6.74	1.53	8.77	1.17	3.70	2.78	3.54	2.91
16	9.66	5.03	1.92	8.77	1.10	3.70	2.61	3.54	2.73
17	10.17	5.03	2.02	8.77	1.16	3.70	2.75	3.54	2.87
18	9.94	5.58	1.78	8.77	1.13	3.70	2.68	3.54	2.81
19	10.21	5.03	2.03	8.63	1.18	3.61	2.83	3.54	2.89
20	9.96	5.03	1.98	8.63	1.15	3.61	2.76	3.54	2.81
21	9.74	5.03	1.93	8.63	1.13	3.61	2.69	3.54	2.75
22	7.80	5.71	1.37	8.63	0.90	3.61	2.16	3.54	2.20
23	6.64	5.71	1.16	7.91	0.84	3.61	1.84	3.32	2.00
Totals & Average ratios	189.42	99.74	***1.89***	199.87	***0.93***	87.81	***2.15***	82.66	***2.27***

from midnight to 0700 hours, while all of the various staff are understaffed (i.e. above average ratios) from 0800-1200 hours. Most of the various types of staff are understaffed well beyond 1200 hours (nurses, medics, and clerks all have above average ratios until 2100 hours). This clearly shows the imbalance in staffing all ED personnel in accordance with the forecasted ED patient arrivals that are shown to be at least 96-97% accurate. Therefore, the overall recommendation is to forecast ED patients

demands by month of the year, day of the week, and hour of the day (i.e. utilizing appropriate indices for each), and then staff all ED personnel according to those forecasted ED patient demands. This recommendation is especially true as the WAMC ED expansion is completed and space is no longer an issue that bottlenecks the flow of patients in the WAMC ED. A graphical depiction of the imbalance displayed in the ratios of Table 20 is provided in Appendix E, Chart 1.

Since space is presently believed to be a significant constraint in the WAMC ED, then Table 21 begins to look at the ratio of patients and staff to WAMC ED spaces (e.g. main ED beds and FT rooms). Ideally, both the ratios in Table 20 above and again in Table 21 below should be about the same by each hour of the day. When these ratios are different it may illustrate when there is not only a constraint on spacing based on the amount of patient arrivals or staffing levels necessary to operate a certain amount of ED spaces, but also a surplus on spacing based on amount of patient arrivals or staffing levels needed. From Table 21, an earlier recommendation of closing a certain amount of main ED beds from 0200-0700 hours is confirmed by the abnormally high beds per patient ratio from 0100-0600 hours (ratio above 5 and well above the 3.44-average). The earlier finding of certain staff members being overstaffed from midnight to 0700 hours is also confirmed to be a timeframe for space surplus by abnormally low ratios of beds per staffing member during these same timeframes (e.g. beds per nurse ratio all below average during this timeframe and same is true for medics). The earlier finding of certain staff members being understaffed from 0900-2100 hours is also confirmed to be a very similar timeframe for space constraint (e.g. beds per patient ratio are all below average from 0800-2200 hours). Therefore, this combination of space constraint and staffing level ratios with those space constraint timeframes illustrates how the ED LOS can get very extended during this timeframe.

The additional WAMC ED expansion is certainly needed as shown not only by the queuing models earlier, but also by these simple staffing ratios that the WAMC ED leadership should regularly monitor to maintain proper spacing and staffing levels that both agree with the ED patient census

Table 21. ED beds in operation to various ED staff ratio by hour of day (combines 1st and 2nd Qtr FY09)

1st/2nd Qtr FY09	# Beds & Rooms	# Providers	Beds / Provider ratio	# Nurses	Beds / Nurse ratio	# Medics	Beds / Medic ratio	# Patients	Beds / Patient ratio
0	22.00	3.03	7.26	7.91	2.78	3.61	6.09	5.63	3.91
1	22.00	3.03	***7.26***	7.91	2.78	3.61	6.09	3.84	***5.74***
2	16.00	2.45	6.53	7.91	***2.02***	3.61	***4.43***	2.79	***5.74***
3	16.00	2.45	6.53	7.64	2.09	3.61	4.43	3.13	5.12
4	16.00	2.45	6.53	7.64	2.09	3.61	4.43	2.79	***5.74***
5	16.00	2.45	6.53	7.64	2.09	3.61	4.43	3.18	5.02
6	16.00	2.45	6.53	7.64	2.09	3.61	4.43	4.18	3.82
7	22.00	3.06	7.18	7.54	2.92	3.70	5.94	6.03	3.65
8	22.00	3.06	7.18	7.54	2.92	3.70	5.94	8.49	2.59
9	22.00	3.06	***7.18***	7.54	2.92	3.70	5.94	10.28	***2.14***
10	22.00	4.06	5.41	7.54	2.92	3.70	5.94	10.99	***2.00***
11	22.00	4.06	5.41	9.48	***2.32***	3.70	5.94	10.93	***2.01***
12	28.00	5.06	5.53	9.48	2.95	3.70	7.56	11.10	2.52
13	28.00	5.06	5.53	9.48	2.95	3.70	7.56	11.07	2.53
14	28.00	5.06	5.53	9.48	2.95	3.70	7.56	10.59	2.65
15	28.00	6.74	***4.15***	8.77	3.19	3.70	7.56	10.29	2.72
16	28.00	5.03	5.56	8.77	3.19	3.70	7.56	9.66	2.90
17	28.00	5.03	5.56	8.77	3.19	3.70	7.56	10.17	2.75
18	28.00	5.58	***5.02***	8.77	3.19	3.70	7.56	9.94	2.82
19	28.00	5.03	5.56	8.63	3.24	3.61	***7.75***	10.21	2.74
20	28.00	5.03	5.56	8.63	3.24	3.61	7.75	9.96	2.81
21	28.00	5.03	5.56	8.63	3.24	3.61	7.75	9.74	2.88
22	28.00	5.71	4.90	8.63	3.24	3.61	7.75	7.80	3.59
23	28.00	5.71	***4.90***	7.91	***3.54***	3.61	7.75	6.64	4.21
Totals & Average ratios	570.00	99.74	5.95	199.87	2.84	87.81	6.49	189.42	3.44

demands by hour of day. Finally, Table 21 above confirms the need to not only benchmark staffing in 4-hour increments (e.g. nursing schedule), but also look at appropriate staffing levels by each hour of the

day. The proper alignment of staffing and spaces with the patient demands by hour of day is best to do simultaneously, and this will allow all of the staffing and spacing ratios to be optimized with patient arrivals and with the amount of space each staff member is responsible for while working (e.g. provider maintains 6 ED beds or 5 FT rooms, nurse maintains 3 ED beds, and medic maintains 2 FT or triage rooms). A graphical depiction of the imbalance displayed in the ratios of Table 21 is provided in Appendix E, Chart 2.

Finding and recommendation #8: WAMC ED Lab and Radiology analysis (Flow as efficiency / cycle times and time-series analysis). Since approximately 44% of all WAMC ED patients receive laboratory orders and approximately 34% of all WAMC ED patients receive a radiology order (i.e. total of 53% of WAMC ED patients receive some ancillary order), then the amount of time it takes to receive results from a laboratory test or radiology exam greatly influences the amount of time a patient spends in the ED. The purpose of this section is to analyze the laboratory and radiology turnaround times (TAT) by the day of the week and the hour of the day. From this analysis, the recommendations include implementing an ED point-of-care testing (POCT) capability as the lab TAT has the most significant impact on the key metric of ED LOS, as well as the WAMC radiology leadership reviewing the TAT results for normal x-rays on the weekends to make some minor staffing adjustments.

An overall average TAT on a radiology order appears to be about 87 minutes, and CHCS splits this time into two pieces (one piece from order time to patient arrival, where ED staff is responsible, and a second piece from patient arrival to results completed, where Radiology staff is responsible). An overall average TAT on a laboratory test appears to be about 74 minutes, and again CHCS splits this time into the same two pieces. The capturing of this TAT data is very difficult to garner from CHCS, as there are many inconsistencies in how the data is collected in CHCS. Certain laboratory and radiology order times to patient arrivals take less than 5 minutes according to CHCS data, and this is nearly impossible

to occur so these sorts of impossibilities have been deleted from the available CHCS data as appropriate. These CHCS data errors occur because of changes to an ancillary order upon patient arrival in CHCS and perhaps even upon results completion (i.e. changes in CHCS order, resets the time in CHCS). Another major inconsistency in CHCS data occurs when unnecessary laboratory or radiology orders are placed in CHCS and never completed for various reasons, and WAMC ED currently has no mechanism to easily delete these unfilled orders that appear to have significantly high TATs when the CHCS data is pulled. Therefore, all ancillary orders that take longer than 480 minutes to occur in total (i.e. 240 minutes for either portion of the ancillary order turnaround) have also been deleted from the CHCS data. This filtered CHCS data set may also be compared to medians by day of the week as appropriate, but since Excel does not allow medians to be calculated inside of pivot tables, it was not feasible to determine median TATs by hour of day.

Table 22. Average ED laboratory cycle time analysis by day of week (compares 1st Qtr FY07 to FY09)

Oct -Dec 2006 with filter	Lab Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)	Oct -Dec 2008 with filter	Lab Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)
Sunday	2557	40.25	35.77	76.02	Sunday	3790	33.59	38.04	71.63
Monday	2870	41.82	44.60	86.43	Monday	4343	33.74	42.82	76.56
Tuesday	2840	40.45	45.08	85.53	Tuesday	4114	31.84	40.38	72.21
Wednesday	2768	40.27	42.95	83.22	Wednesday	4388	34.05	42.56	76.61
Thursday	2483	40.66	43.69	84.35	Thursday	3652	36.33	41.38	77.71
Friday	2536	38.16	42.57	80.74	Friday	3872	31.51	42.97	74.48
Saturday	2274	40.01	37.24	77.24	Saturday	3472	31.03	38.90	69.93
Total and Averages	18328	***40.27***	41.88	82.14	Total and Averages	27631	***33.18***	41.10	74.27
Median without filter	23093	***31***	36	75	Median without filter	34689	***24***	36	68
Median with filter	18328	***32***	33	71	Median with filter	27631	***25***	35	65

Table 22 above shows the average laboratory TATs on ED orders from two distinct time periods, 1st Qtr FY07 (prior to a pneumatic tube emplaced for ED lab orders), and 1st Qtr FY09 (after pneumatic tube was in place). The pneumatic tube was installed in July 2007 and during this same timeframe the WAMC Laboratory combined the chemistry (i.e. probable 15-minute TAT) and immuno-chemistry (i.e. probable 45-minute TAT) assembly lines into one main line of operation (i.e. probable 45-minute TAT). As Table 22 clearly shows the average order to arrival time decreased by over seven minutes (40.27 to 33.18 minutes on average), and this demonstrates a very positive impact that the pneumatic tube has on ED lab orders. Table 22 also shows there were no significant impacts on the main assembly lines of lab being combined, as even with an increase in the amount of ED lab orders of nearly 34% (18,328 to 27,631 orders), the average amount of time taken to complete a lab order decreased from 41.88 to 41.10 minutes on average. Table 22 confirms the changes in average times with the same changes occurring with the median times (e.g. median order to arrival decreasing from 31-32 minutes to 24-25 minutes), as well as median arrival to complete staying relatively true at 35-36 minutes.

Table 23. Median ED laboratory cycle time analysis by day of week (compares 1st Qtr FY07 to FY09)

October - December 2006	Lab Order Count	Median of order to arrival	Median of arrival to complete	Median of order to complete	October - December 2008	Lab Order Count	Median of order to arrival	Median of arrival to complete	Median of order to complete
Sunday	2557	32	**29**	65	Sunday	3790	24	**33**	62
Monday	2870	33	**35**	74	Monday	4343	25	**37**	68
Tuesday	2840	32	**35**	73	Tuesday	4114	25	**35**	66
Wednesday	2768	32	**35**	72	Wednesday	4388	25.5	**35**	67
Thursday	2483	31	**35**	74	Thursday	3652	28	**36**	69
Friday	2536	32	**35**	71	Friday	3872	23	**35**	65
Saturday	2274	31	**29**	65	Saturday	3472	22	**32**	61
Total and Medians	18328	32	33	71	Total and Medians	27631	25	35	65

Table 23 expands on Table 22 analysis of averages by day of week with a median analysis by day of week and agrees with the averages' results, as both show the laboratory portion of the TAT is

distinctly lower on the weekends versus the weekdays. The average Table 22 above shows that it most recently takes around four additional minutes to complete a test on the weekends versus the weekday,

Table 24. Average ED laboratory cycle time analysis by hour of day (compares 1st Qtr FY07 to FY09)

Oct -Dec 2006 with filter	Lab Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)	Oct -Dec 2008 with filter	Lab Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)
0	580	33.64	34.03	67.68	0	946	32.64	37.36	70.00
1	523	36.45	37.46	73.91	1	721	34.15	42.11	76.26
2	461	34.92	36.96	71.88	2	656	31.19	41.99	73.17
3	341	35.17	36.70	71.87	3	616	30.69	40.99	71.68
4	354	32.45	42.64	75.10	4	587	31.86	43.54	75.40
5	385	37.21	41.12	78.33	5	623	29.27	45.76	75.03
6	360	36.62	38.38	74.99	6	523	29.87	42.82	72.70
7	585	38.24	46.87	85.11	7	742	30.95	44.06	75.02
8	792	***39.35***	44.51	83.86	8	1223	***29.00***	45.77	74.77
9	920	***43.25***	47.13	90.38	9	1100	***30.28***	43.33	73.62
10	1085	***41.60***	44.27	85.87	10	1518	***31.24***	44.57	75.81
11	1156	***42.28***	49.23	91.51	11	1467	***33.73***	44.89	78.62
12	953	***43.00***	48.01	91.00	12	1419	***31.39***	42.85	74.24
13	980	***45.00***	41.43	86.43	13	1614	***34.93***	40.59	75.52
14	1027	***43.59***	40.62	84.21	14	1526	***35.38***	40.22	75.60
15	1016	***39.27***	43.14	82.40	15	1385	***33.52***	39.16	72.68
16	998	42.29	41.34	83.62	16	1599	36.63	40.44	77.06
17	889	39.35	41.25	80.61	17	1430	36.18	41.31	77.48
18	916	43.62	35.53	79.16	18	1425	36.14	42.56	78.70
19	796	39.97	43.65	83.62	19	1477	34.21	40.72	74.93
20	968	***41.63***	42.86	84.48	20	1558	***32.21***	38.77	70.98
21	787	***42.73***	39.58	82.32	21	1250	***32.46***	35.86	68.31
22	774	37.15	37.41	74.56	22	1268	33.16	34.85	68.01
23	682	34.65	35.45	70.10	23	958	35.64	36.44	72.08
Total and Averages	18328	40.27	41.88	82.14	Total and Averages	27631	33.18	41.10	74.27

and a complement to this faster TAT is also a much lower amount of laboratory orders being placed (i.e. confirming a lower acuity level of patients on the weekends as shown earlier). This lower median and

average TATs for the lab on the weekends agree perfectly with the lower ED LOS seen most distinctly by the patients who flow through the main ED (i.e. even with a higher census in ED on the weekends).

Table 24 above takes the lab cycle time analysis further by hour of day and shows the impacts of the pneumatic tube was well over 10 minutes less from 0800-1500 hours and again from 2000-2200 hours (heavier portions of ED laboratory orders). Table 24 does not show anything significant by hour of day for the actual laboratory portion of the cycle time. The only minor trend is that from 2000-0100 hours (for 1st quarter FY09 timeframe) the laboratory portion dips below 40 minutes on average for this time period. This trend makes some sense as it is definitely outside of the normal business day and increased demand for the laboratory, although it is not sustained past 0200 hours.

Overall, the recommendations for laboratory analysis includes the use of the pneumatic tube during all timeframes (i.e. sharing positive results with ED staff to encourage using the tube as much as possible) and institute a point-of-care-testing (POCT) capability in the near future within the ED. The POCT does make the lab testing more expensive and even with the laboratory's implementation of an automated system (i.e. RALS plus), the POCT is more personnel resource intensive for the ED to run the lab tests. However, the peaks in certain days of the week (i.e. Monday through Friday) and certain hours of the day (0800-1700 hours) dictate a need for POCT testing during these timeframes.

A possible recommendation to ensure a solid program is implemented during these timeframes includes hiring a laboratory technician position under WAMC ED leadership that runs the POCT capability during this 40-hour timeframe throughout the week. This additional laboratory technician would be able to pull lab orders quickly from POCT, and drastically reduce the 75-minute total TAT on lab orders, and even be able to hand results to the provider and nursing staff instead of waiting for them to be queued as complete in the ED patient tracking application.

Lastly, a business case analysis (BCA) could be performed to look at garnering a larger chemistry laboratory testing machine that agrees with the testing results performed in the main lab. A larger chemistry machine performs the majority of chemistry lab orders from the ED much faster than the POCT option, and is possibly less expensive in the long run as the expendable supplies needed to perform the test are cheaper. An additional savings for a larger testing machine may be garnered by negotiating the machine to be on a free lease in WAMC ED pending a certain amount of expendable supplies are ordered periodically. This larger chemistry testing machine could re-establish a 15-minute TAT for a large amount of ED lab orders, and significantly lower the 75-minute total TAT average. A recommendation would be to conduct a formal BCA to determine the cost effectiveness of establishing a larger chemistry testing machine in the ED, and submit the BCA for funding in the bi-annual U.S. Army Medical Command Advanced Medical Practice initiatives.

Table 25 shifts gears from laboratory TAT to radiology TAT, and begins by showing the

Table 25. Average ED radiology TAT analysis by day of week (compares 1st Qtr FY07 to FY09)

Oct -Dec 2006 with filter	Rad Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)	Oct -Dec 2008 with filter	Rad Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)
Sunday	523	32.45	56.95	89.40	Sunday	858	29.71	***62.42***	92.13
Monday	696	32.09	56.99	89.09	Monday	842	35.10	***47.03***	82.13
Tuesday	695	29.01	51.22	80.23	Tuesday	837	31.25	55.86	87.11
Wednesday	738	27.24	51.45	78.70	Wednesday	930	34.13	54.18	88.32
Thursday	708	28.61	56.77	85.38	Thursday	886	29.10	50.52	79.63
Friday	634	27.38	53.17	80.55	Friday	843	31.12	51.27	82.39
Saturday	570	28.60	***64.08***	92.69	Saturday	869	30.91	***62.79***	93.70
Total and Averages	4564	29.25	***55.53***	84.78	Total and Averages	6065	***31.63***	***54.88***	***86.51***
Median without filter	7920	10	37	58	Median without filter	10619	9	34	56
Median with filter	4564	17	37	66	Median with filter	6065	***19***	***37***	***69***

differences by day of week from the 1st quarter of FY07 to the 1st quarter of FY09. Ironically, the opposite trends of the laboratory analysis are seen with the radiology analysis. First, the radiology portion of the radiology procedure TAT is much longer on the weekends (i.e. above 62 minutes versus an average below 55 minutes), and it is significantly lowest on Monday (i.e. 47.03 minutes on average). The opposite is true with the laboratory TAT (shortest on weekend and longest on Monday) and the opposite is also true with the overall ED LOS (shortest on weekend and longest on Monday). Part of the reason is that a smaller portion of ED patients have a radiology order (i.e. 34%) versus a laboratory order (i.e. 44%), and another large part of the reason is that radiology is not fully operational throughout the entire weekend on certain radiology exams. Furthermore, the in-depth radiology analysis shows that CT scans (27.3% of ED radiology tests), MRIs (.4%), and ultrasounds (9.5%) are really getting the same radiology processing time on weekends versus weekdays. The only exception was CT scans on Sunday took 46.85 minutes on average, versus 30.60 minutes on Monday, or 36.24 minutes average overall. The majority of ED radiology orders (i.e. 63.2%) are just regular x-rays, and here is where the difference arrives in processing time on weekends (i.e. 67.09 minutes on Saturday, 60.4 minutes on Sunday, 48.25 minutes on Monday, and 55.95 minutes overall for regular x-rays). This analysis demonstrates there is a need for the Department of Radiology leadership to look at their exam processing times and the staffing and/or communication pitfalls associated with these times on the weekends versus the weekdays. Even if it does not show there is as much of an impact overall on the ED LOS in the negative, it could have a significant positive impact on the ED LOS on the weekends and overall throughout the rest of the week.

Table 25 does show that there is a significant difference between the average (31.63, 54.88, and 86.51 minutes) and median (19, 37, and 69 minutes) with the same filter being applied as explained

earlier in the laboratory analysis. This large difference between the averages and medians across all time portions (i.e. order to arrival for ED portion, arrival to complete for Radiology portion) shows that there are a significant amount of outliers (i.e. patients taking an abnormally longer amount of processing time). These outliers are where significant improvements can be made in the quality of care for those patients specifically, but quite probably in the amount of time necessary to flow other patients through the ED in a timely manner overall. The previous in-depth analysis also showed the CT scans (average 36.24 minutes of processing time, with only significant variation on Sundays at 46.85 minutes on average) and ultrasounds (average 40.73 minutes of processing time, with no significant variations on any day of the week) were not the culprit. This demonstrates that radiology is very responsive to acute ED radiology needs. The real outliers seemed to be in the normal radiographic exams (average 55.95 minutes of processing time, with a wide range of 48.25 minutes on Monday to 67.09 minutes on Saturday). Any efforts to significantly reduce the outliers in normal radiographic exams on the weekends may have a significant impact on the quality of care provided to those patients and overall patient flow in the ED. This is true anecdotally, even if the ED metrics do not confirm the need for

Table 26. Median ED radiology TAT analysis by day of week (compares 1st Qtr FY07 to FY09)

October - December 2006	Rad Order Count	Median of order to arrival	Median of arrival to complete	Median of order to complete	October - December 2008	Rad Order Count	Median of order to arrival	Median of arrival to complete	Median of order to complete
Sunday	523	20	39	72	Sunday	858	19	***43***	78
Monday	696	18	38	70.5	Monday	842	20	***31***	65
Tuesday	695	18	35	62	Tuesday	837	18	36	68
Wednesday	738	16	36	64	Wednesday	930	20	36	70
Thursday	708	17	40	68.5	Thursday	886	17	34	63
Friday	634	17	36	60	Friday	843	18	36	67
Saturday	570	17.5	***42***	69	Saturday	869	17	***44***	80
Total and Medians	4564	17	***37***	66	Total and Medians	6065	19	***37***	69

improvements in this area. Table 26 above also confirms through median analysis that most of the

outliers again occur consistently on Saturday and Sunday (medians of 43-44 minutes versus a 37 minute median overall).

Table 27. Average ED radiology TAT analysis by hour of day (compares 1st Qtr FY07 to FY09)

Oct -Dec 2006 with filter	Rad Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)	Oct -Dec 2008 with filter	Rad Order Count	Average of order to arrival (5-240 minutes)	Average of arrival to complete (10-240 minutes)	Average of order to complete (15-480 minutes)
0	141	33.49	63.18	96.67	0	211	34.41	53.92	88.34
1	113	25.67	58.38	84.05	1	161	33.31	57.82	91.13
2	84	34.57	57.93	92.50	2	162	38.19	***76.19***	114.38
3	76	38.45	53.09	91.54	3	198	39.61	***72.74***	112.35
4	71	40.82	35.77	76.59	4	147	***40.05***	54.92	94.97
5	72	39.96	44.33	84.29	5	134	29.24	***36.90***	66.13
6	95	34.37	35.94	70.31	6	111	31.30	***32.20***	63.50
7	141	21.78	54.52	76.30	7	136	31.24	55.35	86.59
8	191	22.82	47.57	70.39	8	202	28.63	45.40	74.02
9	229	25.55	53.90	79.45	9	238	29.68	61.48	91.16
10	241	27.71	51.63	79.33	10	278	29.60	58.28	87.88
11	285	35.30	53.67	88.98	11	316	33.61	66.65	100.25
12	235	27.96	47.71	75.68	12	325	29.00	67.56	96.56
13	216	32.19	52.81	85.00	13	356	28.41	56.22	84.63
14	267	29.16	55.85	85.01	14	329	28.22	52.91	81.13
15	261	29.79	64.35	94.14	15	308	***27.86***	53.70	81.56
16	245	31.74	71.48	103.22	16	369	28.18	57.28	85.46
17	282	27.69	62.44	90.13	17	301	38.38	47.87	86.25
18	261	28.53	57.57	86.10	18	370	30.02	54.79	84.81
19	210	32.12	61.41	93.53	19	332	31.55	51.12	82.67
20	253	25.32	51.66	76.98	20	307	29.36	53.81	83.17
21	240	25.44	58.84	84.28	21	274	28.97	42.82	71.79
22	204	26.33	50.28	76.61	22	269	31.82	38.73	70.55
23	151	28.09	54.45	82.54	23	231	***41.15***	55.63	96.78
Total and Averages	4564	29.25	55.53	84.78	Total and Averages	6065	31.63	***54.88***	86.51

Finally, the radiology analysis by hour of day is shown above in Table 27 and shows in the 1st quarter FY09 timeframe that the worst radiology TAT occur from 0200-0400 hours versus all other hours throughout the day (averaging nearly 75 minutes versus a 55 minute overall radiology portion of the entire TAT). Ironically, these are two hours of very low radiology demand from the ED, and the potential amount of time for improvement is seen in the 0500-0700 timeframe where the average radiology portion of the TAT dropped to under 35 minutes or 20 minutes below the average and 40 minutes below the average from 0200-0400 hours. This variation is where improvements may be garnered from the 0500-0700 hours radiology staff, and passed along to the staff from 0200-0400 hours. Any improvements to reduce the variation in radiology TAT will improve care given to ED patients.

During these same timeframes, the ED staff seems to follow a similar trend of the radiology staff, as it takes nearly 10 minutes longer to arrive a patient from 0200-0400 hours as it does from 0500-0700 hours. This difference may again highlight some communication difficulties occurring between the ED and radiology staff from 0200-0400 hours that are usually remedied with the opposite impact from 0500-0700 hours. Overall, the recommendations from the radiology analysis do not depict any significant changes for the WAMC ED leadership, and perhaps key in on a couple areas that the Department of Radiology leadership may look at in making improvements to support ED patients consistently throughout the weekend and late night to early morning hours.

Finding and recommendation #9: WAMC ED PA-triage system and Advanced RN-triage protocols analysis (Flow as empowered providers exceeding expectations and time-series analysis). The purpose of this section is to analyze the results from the PA triage system pilot study conducted in September 2008, as well as the Advanced RN-triage protocols that are put into operation after WAMC ED is in bed-lock. In principle, both of these procedures allow for initial treatment of main ED patients to begin before placing the patient in the main ED treatment area, and both should allow the ED LOS to

be shortened. However, the application of these procedures has not been implemented in either a robust way (e.g. PA triage system seeing only 20% of patients), nor in an aggressive way (e.g. Advanced RN-triage protocol implemented only after WAMC ED bed-lock). Therefore, the recommendations support earlier analysis to combine staffing efforts of both procedures, and implement a robust, aggressive way to initiate main ED treatment through an MD/PA triage system as described in the queuing models analyses.

As explained earlier, CPT George Barbee (WAMC ED physician assistant currently deployed) completed a study in September 2008 on whether or not a PA-triage system made up of himself and one medic for 8-hour time periods on various Monday, Wednesday, and Fridays would have a positive impact on the average WAMC main ED LOS. The results showed no overall impact (no significant difference based on comparative statistical analysis conducted) between the average WAMC main ED LOS with or without the PA-triage system in operation. However, there was a considerable impact (significant difference based on comparative statistical analysis conducted) between the average WAMC main ED bed service rate with or without the PA-triage system in operation. The considerable impact showed the average main ED bed service rate reduced from 3 hours, 49 minutes to 2 hours, 9 minutes, as well as the median main ED bed service rate reduced from 3 hours, 30 minutes to 1 hour, 35 minutes.

The drawbacks to the study included a sampling of only about 18 patients each day the triage was conducted, and only about 13 patients each day the triage was not conducted (in order to gain a comparable sampling of patients with the same chief complaint and diagnosis from the ED all patients with ESI level 3 only participated in the study). This sampling is less than 20% of the amount of patients seen in the main ED throughout the day (less than 33% for that 8-hour time period). ESI level III patients were the only patients seen in the study and these patients are the least acute of the patients seen in the main ED (ESI level 1-2 patients are higher in acuity, but PA is not certified to treat). The

lack of any significant difference in main ED LOS is easily explained by these study limitations. As Table 28 summarizes below, the queuing model analysis showed a distinct possibility in eliminating main ED bottlenecks if the PA-triage system could be implemented at a level that saw all of the main ED patients in the triage area (e.g. queuing comparisons show a drop from 186.69 to 123.17 minutes).

Table 28. Comparison of main ED bed server rates by hour of day without & with PA triage capabilities

Hour	Main ED Bed Arrival Rate	Main ED Bed Server Rate w/o PA triage	Main ED Beds	Avg time in system (min)	% of time (min)	Main ED bed Server Rate with PA triage	Main ED beds	Avg time in system (min)	% of time (min)
0	4.55	0.33	16	209.00	8.33	0.5	16	120.48	4.80
1	3.80	0.33	16	185.74	6.19	0.5	11	126.69	4.22
2	2.82	0.33	12	189.69	4.68	0.5	11	120.75	2.98
3	3.15	0.33	12	202.87	5.59	0.5	11	121.67	3.35
4	2.76	0.33	12	188.28	4.56	0.5	11	120.64	2.92
5	3.13	0.33	12	201.94	5.53	0.5	11	121.61	3.33
6	3.98	0.33	16	188.71	6.58	0.5	11	129.40	4.51
7	3.12	0.33	16	180.93	4.94	0.5	11	121.58	3.32
8	4.45	0.33	16	203.55	7.92	0.5	16	120.38	4.69
9	5.40	0.33	23	182.05	8.60	0.5	16	122.31	5.78
10	5.88	0.33	23	185.28	***9.53***	0.5	16	125.00	***6.43***
11	5.70	0.33	23	183.76	***9.17***	0.5	16	123.78	***6.17***
12	6.13	0.33	23	188.32	***10.10***	0.5	16	127.32	***6.83***
13	5.95	0.33	23	186.04	***9.69***	0.5	16	125.59	***6.54***
14	5.77	0.33	23	184.33	***9.31***	0.5	16	124.24	***6.28***
15	5.67	0.33	23	183.53	***9.10***	0.5	16	123.59	***6.13***
16	5.09	0.33	23	181.05	8.06	0.5	16	121.35	5.41
17	5.36	0.33	23	181.88	8.53	0.5	16	122.16	5.73
18	4.98	0.33	23	180.81	7.87	0.5	16	121.10	5.27
19	5.38	0.33	23	181.98	8.57	0.5	16	122.25	5.76
20	5.30	0.33	23	181.67	8.43	0.5	16	121.96	5.66
21	5.93	0.33	23	185.78	9.64	0.5	16	125.39	6.50
22	5.12	0.33	23	181.13	8.12	0.5	16	121.43	5.44
23	4.83	0.33	23	180.57	7.63	0.5	16	120.83	5.11
Totals	110.08				***186.69***				***123.17***

Another limitation in the PA-triage study completed by CPT Barbee was the space and amount of support staff utilized to complete PA-triage on the more than 18 ESI level III patients seen daily over a 8-hour timeframe (normally 1000-2200 hours or peak hours in ED patient arrivals). The space allocated was two triage rooms, and the support staff allocated was one medic. This space could easily be increased to the three triage rooms now available and ideally should be expanded to include another room originally designed to hold four ED beds as the air evacuation holding area (currently being used for ED storage). This capability of seven ED treatment areas in the triage area would allow an MD/PA triage team to be instituted and increase its ability to perform initial treatments (including laboratory & radiology orders) on all main ED patients from ESI level II through III (ESI level I patients are immediately brought into ED trauma room). The WAMC ED MD would likely see all ESI level II patients and the PA would likely see all ESI level III patients primarily. As Table 28 shows, this would likely decrease the average ED LOS by more than 63 minutes (186.69 to 123.17 minutes), and the MD/PA triage system would again find its most significant benefits during the peak ED patient arrivals from 1000-2200 hours.

Overall and based on the current space constraints in the main ED now (16 main ED beds with current census) and in the future (23 main ED beds with increased ED census likely with population growth increases occurring over the next 2-3 years), the WAMC ED leadership should institute advanced triage procedures and has taken an initial step to do so by conducting this study. Within the current space configuration of the ED, this MD/PA triage could be fully implemented (expand from two to seven triage treatment spaces) and shows a very distinct probability in improving the patient flow dramatically within the main ED area where the majority of the patient bottlenecks exist. Another step that the WAMC ED leadership has already taken and needs to continually improve its operation is the advanced RN triage protocols instituted.

Currently there are 10 advanced triage protocols that can be implemented by the triage RN to include prescribing Tylenol, Motrin or Benadryl, ordering lab tests for pregnancy or urinanalysis, ordering extremity x-rays on ESI level III through V patients, initiating treatment on dyspnea (disease of airway, lungs, and heart) or chest pain to include EKG, chest x-ray, IV infusion of certain medications (albuterol for patients with history of chronic obstructive pulmonary disease), and ordering various lab tests for patients with vomiting, diarrhea, or abdominal pain. These 10 advanced triage protocols were initiated by WAMC ED leadership as a result of the PA-triage study conducted by CPT Barbee, and fully implementing these 10 advanced triage protocols should have a very positive impact on the ED LOS. A risk with implementing these advanced triage protocols without an increase in the triage RN staffing levels may cause problems to occur that did not occur during CPT Barbee's study. Since these 10 advanced triage protocols were instituted around the same time as the EDPTA to follow in the next section (over last 2 months), some of the key ED metrics will be looked at for positive or negative impacts seen thus far.

Over the last two months in February and March 2009, there has been an expected increase in the ED patient census (these two months are historically well above average ED census levels). Coincidentally, with the increased ED census and other constraints on ED staff (e.g. EDPTA implementation, advanced RN triage protocols initiation, and increased ED provider deployment levels) one of the key ED metrics (LWOBS) is headed in the wrong direction. For the first time in over 24 months, the WAMC ED LWOBS percentage has gone above 10% for two consecutive months, 11.3% in February and 13.2% in March 2009 (percentage in February 2008 was 10.7% and next previous month above 10% was February 2007 at 15.7%). These are not good trends and perhaps point to increased levels of triage staffing needed when instituting triage protocols (10 advanced protocols only implemented during WAMC ED bed-lock or all WAMC main ED beds are full), as well as nursing staff

jobs being redesigned to ensure other support staff are instrumental in inputting information into EDPTA (relieving any burdens possible on WAMC ED nursing staff). These areas will be expanded upon in the final section below, but a recommendation for the 10 advanced RN triage protocols would be to schedule nursing staff for them appropriately and implement on all patients from 1000-2200 hours or peak ED patient arrivals. A reactive system to ED bed-lock will not have a positive impact on ED LWOBS nor ED LOS, as it fails to preempt ED bottlenecks.

Finding and recommendation #10: WAMC ED Patient tracking application (EDPTA) and QMatic software installation (Flow as systems thinking and pattern building analytic technique). In the last several months the WAMC ED received two new patient tracking applications (EDPTA and QMatic) and the initial results (e.g. ED key metrics) of these systems show a need to ensure WAMC ED staffing responsibilities are redesigned for easy input and quick response capabilities to these systems. Both EDPTA and QMatic are not fully implemented to varying degrees and are therefore not providing the optimum amount of decision-making capabilities to either WAMC ED or Command leadership in proper staffing and system administrative support. The recommendation of this section is to fully implement the usage of both EDPTA and QMatic, and 100% usage will allow accurate data analysis to be performed from both applications to make future ED operational improvements.

In November 2008, the WAMC Information Management Division (IMD) began programming updates on an ED patient tracking application (EDPTA) that was developed at Jacksonville Naval Hospital (NH) in Florida and given to WAMC IMD for free as a collaborative effort to improve the functionality of the application. WAMC IMD has since given Jacksonville NH staff the CHCS cache program updates created to make an even more effective tracking application in the WAMC ED. EDPTA completely replaces the use of a dry-erase whiteboard in the main ED area, and provides a possible tracking tool to improve patient flow in the FT area. In February 2009, WAMC IMD and ED

agreed to go live with a 6-month pilot study on EDPTA, and since this time the WAMC ED leadership attempted to mandate its use rather effectively in the Main ED area and has experienced very limited success in its usage in the FT area. Table 29 estimates some of the short-term impacts by hour of day (difference between the average main ED LOS from Oct 08-Jan 09 timeframe to Feb 09-Mar 09

Table 29. Estimated short-term and long-term impacts on Main ED LOS from EDPTA implementation

Hour of Day	Feb 09 - Mar 09 LOS Average	Oct 08 - Jan 09 LOS Average	Feb 08 - Mar 08 LOS Average	Short Term LOS Impact	Long Term LOS Impact	Feb 09 - Mar 09 LWOBS Average	Oct 08 - Jan 09 LWOBS Average	Feb 08 - Mar 08 LWOBS Average	Short Term LWOBS Impact	Long Term LWOBS Impact
00	290.38	253.13	248.70	37.24	41.68	1.27	0.69	0.85	0.58	0.42
01	259.31	243.27	248.42	16.03	10.88	0.66	0.37	0.60	0.30	0.06
02	214.66	214.54	218.29	0.11	-3.63	0.31	0.19	0.43	0.12	-0.13
03	236.12	191.31	213.54	44.81	22.58	0.19	0.17	0.23	0.02	-0.05
04	200.71	186.74	188.82	13.96	11.88	0.17	0.09	0.20	0.08	-0.03
05	162.31	173.34	168.28	-11.03	-5.97	0.17	0.10	0.15	0.07	0.02
06	189.09	176.39	164.08	12.71	25.01	0.19	0.05	0.05	0.14	0.14
07	203.09	183.78	186.32	19.31	16.78	0.17	0.05	0.08	0.12	0.09
08	200.66	188.88	187.38	11.78	13.28	0.31	0.06	0.18	0.25	0.12
09	219.07	209.09	200.94	9.98	18.13	0.68	0.28	0.28	0.40	0.39
10	253.93	220.71	224.23	33.22	29.70	0.98	0.58	0.45	0.41	0.53
11	250.02	223.18	240.22	26.84	9.79	0.98	0.54	0.90	0.45	0.08
12	295.59	248.68	239.57	46.92	56.02	1.17	0.92	0.85	0.25	0.32
13	259.64	253.73	259.47	5.91	0.18	1.29	0.82	0.62	0.47	0.67
14	298.43	246.68	231.73	***51.75***	***66.70***	1.68	0.86	1.27	0.82	0.41
15	294.71	265.53	274.41	29.18	20.30	1.53	1.11	1.37	0.41	0.16
16	308.95	268.21	251.63	40.74	57.32	1.69	1.00	1.13	0.69	0.56
17	276.99	270.48	247.49	6.50	29.49	1.64	0.79	1.13	0.86	0.51
18	261.18	265.93	243.32	-4.75	17.86	1.36	0.91	1.03	0.45	0.32
19	283.81	275.60	234.15	8.21	49.66	1.81	0.89	1.43	0.93	0.38
20	293.52	261.63	246.60	31.89	46.92	1.58	0.90	1.03	0.67	0.54
21	281.49	256.36	226.15	25.13	55.34	1.95	0.89	1.00	1.05	0.95
22	286.55	246.93	234.56	39.63	51.99	2.00	0.75	1.05	***1.25***	***0.95***
23	244.49	233.53	215.81	10.96	28.67	1.54	0.85	0.78	0.69	0.76
LOS Averages & LWOBS Totals	252.70	231.57	224.76	***21.13***	***27.94***	25.31	13.85	17.12	***11.46***	***8.19***

timeframe) and long-term impacts by hour of day (difference between the average main ED LOS from Feb 08-Mar 08 timeframe to Feb 09-Mar 09 timeframe).

As stated earlier, in the last two months there have not only been changes in the implementation of these tracking applications, but also the experienced provider staffing levels have decreased due to recent deployments (including the WAMC ED provider chief is deployed and being replaced 1 May 2009). February and March are also higher than average ED census months, with March 2009 exceeding all forecasts due to a belated flu season at Fort Bragg this year. Based on the LOS Averages and LWOBS Totals line in Table 29 above, the short-term impact on the main ED LOS is 21.13 minutes more leading to 11.46 more LWOBS patients, and the long-term impact is 27.94 minutes more on the main ED LOS leading to 8.19 more LWOBS patients. It is noteworthy to remember that not all of the LWOBS occur in the main ED area, but currently all LWOBS are coded in CHCS as occurring from the main ED. Some of the largest increases in ED LOS and LWOBS by hour of day are also highlighted in Table 29 and demonstrate the demands of adapting to a new application may be increasing these key metrics significantly in the wrong direction.

As stated in the previous section, over the last two consecutive months the LWOBS percentage has been well above 10% for the first time in over two years. As stated earlier, the EDPTA is rarely being used as a tracking application for the FT area (according to anecdotal evidence from the first couple of months in the pilot study and confirmed by WAMC ED leadership). WAMC ED leadership acknowledges it is difficult to staff the charge nurse consistently in the FT area, and this staffing inconsistency probably leads to a lack of emphasis on EDPTA usage. The registration clerks would benefit the most from EDPTA usage in both the FT and main ED areas, but are responsible for very little input and upkeep on the application. Therefore, the level of knowledge on EDPTA by various ED staff is not sufficient to realize the potential benefits it could offer in tracking patients and gaining updated

status on FT or main ED patients very quickly on any computer workstation. Even though EDPTA has not been adopted in the FT area, there have been possible short-term and long-term impacts to the FT LOS, since patient flow challenges in the main ED also impact the FT area.

Table 30. Estimated short-term and long-term impacts on FT LOS from EDPTA implementation

Hour of Day	Feb 09 - Mar 09 FT LOS Average	Oct 08 - Jan 09 FT LOS Average	Feb 08 - Mar 08 FT LOS Average	Short Term FT LOS Impact	Long Term FT LOS Impact
00	235.19	175.73	140.28	***59.46***	***94.92***
01	235.38	172.85	224.00	62.52	11.38
02	233.07	170.51	339.40	62.56	-106.33
03	225.49	179.32	287.67	46.16	-62.18
04	147.26	160.52	203.18	-13.26	-55.92
05	148.15	136.15	167.64	12.00	-19.49
06	123.58	109.18	122.40	14.40	1.17
07	107.92	102.54	109.11	5.38	-1.19
08	122.32	111.67	119.50	10.65	2.82
09	163.17	140.74	138.58	22.44	24.59
10	182.11	151.22	171.36	30.89	10.75
11	198.25	157.39	173.49	40.87	24.77
12	194.82	166.05	183.94	28.77	10.89
13	199.04	164.93	162.48	34.11	36.56
14	203.70	168.09	161.79	35.61	41.91
15	197.34	174.97	157.15	22.37	40.19
16	211.69	175.46	165.37	36.23	46.33
17	208.04	173.37	164.34	34.67	43.70
18	219.37	182.62	158.44	36.75	60.93
19	238.34	183.34	178.33	55.00	60.01
20	223.66	193.13	156.30	30.53	67.36
21	215.59	205.31	165.36	10.28	50.22
22	203.35	180.24	147.45	23.11	55.90
23	227.41	154.31	119.34	***73.10***	***108.07***
LOS Averages	194.34	162.07	171.54	***32.28***	***22.81***

Table 30 above depicts the average increases in the FT LOS and particular hours of interest for the FT are those hours leading up to its current closure at 0200 hours. Overall the short-term FT LOS impact was an increase of 32.28 minutes, and long-term impact of 22.81 minutes. Again, it is currently not possible to depict how many LWOBS are occurring from the FT area based on the way the encounters are coded in CHCS.

As of 10 June 2009, the QMatic application is still not fully installed and working in the WAMC ED triage area and this prevents any concrete data analysis on the amount of time it may be taking patients to see the triage nurse. The lack of a QMatic application prevents the WAMC Command leadership from fully realizing the amount of time it may be taking to see the triage nurse, as that time is not included in the average ED LOS currently. Anecdotal evidence shows that this time may be anywhere from 0-90 minutes depending upon the amount of patient arrivals during particular timeframes of the day. The lack of a QMatic application prevents the WAMC ED leadership from fully realizing how much triage staff is needed on particular hours of the day and days of the week, as well as a capability to proactively staff more or less triage nurses when an abnormal amount of patient arrivals occur. Finally, the lack of a QMatic application prevents either the WAMC Command or WAMC ED leadership from researching how many patients present to the ED and depart before even seeing the triage nurse (many civilian ED's define this as an ED LWOBS, and any patient who leaves after seeing the triage nurse is defined as left before treatment complete – LBTC). The analysis of QMatic data remains a future challenge for WAMC ED leadership, and there are several other ED challenges in the near future.

Future challenges

The fastest approaching challenge for the ED and therefore perhaps one of the most significant is mandated to occur within the summer 2009 timeframe. The Office of the Surgeon General (OTSG) for

the Army has mandated that all ED encounters are coded in AHLTA and a scanned version of the ED hardcopy medical record is placed into the AHLTA encounter under the 'Add a Note' section. This change requires the registration clerks to create an AHLTA encounter versus a CHCS encounter as is currently being done, and the ED provider would have to sign the AHLTA encounter versus a CHCS encounter. This change also requires new work to be completed in acquiring the scanned version of the hardcopy medical record (currently being scanned by ED coding contractor for coding purposes) and adding this scanned document to the AHLTA encounter (new work needs to be completed by WAMC Patient Administration Division (PAD) staff). OTSG is requiring these ED encounters to be captured in AHLTA in a timely manner (within 24-48 hours), and WAMC PAD is already understaffed (e.g. awaiting hiring actions) to eliminate a backlog of network specialty care results being posted into AHLTA in a similar manner. The new work possibly requires some of the duties and responsibilities to be shared by WAMC ED registration clerks if possible (especially those WAMC ED registration clerks not as busy on late-night shifts).

An even greater challenge that will likely take place over the next two years is a transition to the Essentris ED module becoming the mandated electronic record for all Department of Defense (DoD) ED patients (Essentris ED module in beta-testing at San Diego NMC and Madigan AMC). The Essentris ED module is under improvement to gain bi-directional communication capabilities with AHLTA/CHCS, and this is a significant improvement that needs to be made before it is fielded to the entire DoD. Another challenge with the Essentris ED module is with provider's inputting information into the electronic medical record, and this is easily overcome at locations like San Diego NMC and Madigan AMC with ED provider residency programs (resident providers input information into Essentris for staff ED providers). Improvements being implemented under the MEDCOM AHLTA Provider Satisfaction (MAPS) initiative include some middleware (software that allows user links into

AHLTA/Essentris) applications such as Dragon Natural Speak and As You Type that allow providers to easily input information into AHLTA/Essentris (eliminates expensive options such as transcription of ED records into Essentris as already shown at San Diego NMC). The Essentris ED module would also negate the usage of EDPTA, but offers some patient tracking application capabilities within Essentris that need to be explored and improved upon during the beta-testing of the ED module.

Dependent upon EDPTA being fully adopted within the main ED and FT areas at WAMC, along with QMatic being fully implemented and used for a significant time period in the WAMC triage area, there will be another challenge in properly analyzing the data from those applications. Both applications will allow for a greater level of detail with certain areas of ED patient flow. For example, EDPTA will offer the capability to analyze main ED room utilization rates, especially in comparison with the main ED specialty rooms (e.g. two Ortho rooms and two OB/Gyn rooms) to ensure how many rooms and what type of rooms are needed for the WAMC ED to optimally operate. QMatic data analysis will be able to explore the amount of time a patient is waiting to see a triage nurse by hour of day and day of week, and in conjunction with experienced QMatic data analysts in the pharmacy and laboratory areas of WAMC other distinct data analysis may help find misalignments of WAMC ED staff with patient demands.

One present challenge will also be a future challenge and that is how to maximize the amount of patients seen in the FT area to relieve the main ED area of as many patients as possible. Therefore, a future challenge that has not been formally planned into the ED expansions of WAMC's Master Facility plan include an expansion from 12 to 16 FT rooms. As Table 31 shows below, there are a significant amount of non-urgent patients (as coded in CHCS) that are treated in the main ED (particular hours are highlighted in Table 31). It is likely that an MD/PA triage system will allow more of the ESI level III patients to be seen in the FT area, as these are likely the patients being coded in CHCS as non-urgent.

The implementation of a robust MD/PA triage system needs all 7 treatment spaces to be utilized in order to be successful, and this is something else not include in the WAMC ED formal expansion plans.

Table 31. Non-urgent patients seen in the main ED by hour of day for 6 months of FY09

Non-urgent patients seen in main ED by hour of day	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Total	Average
00	47	27	13	26	27	32	172	***0.95***
01	31	27	24	18	9	22	131	***0.72***
02	19	13	23	18	11	23	107	0.59
03	17	22	18	13	10	22	102	0.56
04	20	12	7	9	17	18	83	0.46
05	23	18	15	13	7	22	98	0.54
06	14	5	22	12	9	13	75	0.41
07	19	12	13	21	18	20	103	0.57
08	23	19	19	29	33	13	136	***0.75***
09	32	27	23	27	17	31	157	***0.86***
10	29	35	28	20	20	20	152	***0.84***
11	22	36	10	13	13	19	113	***0.62***
12	19	18	30	14	12	12	105	0.58
13	18	22	10	18	10	9	87	0.48
14	19	21	12	13	17	7	89	0.49
15	9	24	17	9	12	7	78	0.43
16	8	10	6	6	4	3	37	0.20
17	8	19	10	11	4	16	68	0.37
18	13	19	6	14	9	10	71	0.39
19	15	23	11	9	12	11	81	0.45
20	27	22	17	15	17	15	113	***0.62***
21	29	21	29	19	35	39	172	***0.95***
22	39	24	28	30	28	72	221	***1.21***
23	55	23	24	26	45	44	217	***1.19***

Another future challenge for ED leadership is to develop data tracking applications that allow for ESI levels to be collected on every patient encounter. This data would then allow the ED leadership to make staffing decisions by hour of day on not only ED census, but also from patient acuity levels seen on average throughout the day. ESI levels are able to be analyzed today by month of the year (see Table

32 below) and day of the week (see Table 33 below). The tables below show that there are no significant seasonal changes in ESI level by month, or any significant changes in ESI level by day of the week.

Table 32. Emergency Severity Index level average percentages for every month in 2008

Month in 2008	ESI Cat 1	ESI Cat 2	ESI Cat 3	ESI Cat 4	ESI Cat 5	ED Percentage	FT Percentage
January	0.12%	19.83%	34.27%	32.36%	13.42%	54.22%	45.78%
February	0.04%	19.85%	29.98%	36.31%	13.82%	49.87%	50.13%
March	0.17%	16.83%	34.43%	36.74%	11.84%	51.43%	48.57%
April	0.08%	16.99%	32.57%	38.44%	11.92%	49.64%	50.36%
May	0.10%	18.76%	31.70%	36.16%	13.28%	50.56%	49.44%
June	0.08%	16.75%	33.35%	37.12%	12.70%	50.17%	49.83%
July	0.12%	18.93%	32.14%	39.01%	9.81%	51.18%	48.82%
August	0.02%	14.99%	32.34%	41.29%	11.37%	47.35%	52.65%
September	0.25%	18.03%	31.40%	38.91%	11.40%	49.68%	50.32%
October	0.13%	17.64%	30.95%	41.06%	10.22%	48.72%	51.28%
November	0.58%	15.56%	30.97%	41.47%	11.43%	47.11%	52.89%
December	2.06%	18.16%	32.32%	40.07%	7.39%	52.54%	47.46%

Table 33. Emergency Severity Index level average percentages for every day of the week in 2008

Day of Week (CY08 data)	ESI Cat 1	ESI Cat 2	ESI Cat 3	ESI Cat 4	ESI Cat 5	ED Percentage	FT Percentage
Sunday	0.26%	15.56%	30.78%	40.66%	12.73%	46.75%	53.25%
Mon	0.31%	17.90%	32.38%	37.28%	12.13%	50.76%	49.24%
Tue	0.39%	18.41%	31.81%	38.20%	11.20%	50.62%	49.38%
Wed	0.24%	18.54%	33.49%	37.66%	10.07%	52.37%	47.63%
Thu	0.28%	19.11%	33.21%	36.88%	10.52%	52.81%	47.19%
Fri	0.32%	18.05%	33.26%	36.96%	11.41%	51.68%	48.32%
Sat	0.32%	16.59%	30.55%	39.86%	12.68%	47.49%	52.51%
Average	0.30%	17.70%	32.18%	38.25%	11.56%	50.36%	49.64%

Some of the ED patient flow recommendations are likely not going to be followed at WAMC and were not all included in the findings and recommendations. These include doing some sort of ED patient mini-registration up front before the nurse triages the patient, and this would be especially

important when there is a wait to see the triage nurse. If the wait to see a triage nurse was kept to a bare minimum, then this would not be a problem (recommendation is to keep the triage wait to a minimum 15 minutes or less). Another way is to somehow make the wait times more transparent to the patients, and this is possible with WAMC's implementation of the QMatic application, although it becomes very tricky as patients are seen by triage level and not on a first-come, first-serve basis. Any improvement in this area would improve the patient anxiety level that is sometimes palpable in the WAMC ED waiting area. This fact has been stated already and will be stated again later, but hospital-wide patient flow data analysis for WAMC should at least include OR data, ED data, inpatient data, and outpatient data. In fact, an initial study completed (thanks to real-time outpatient data from Charlene Colon) on the amount of primary care appointments in the AM versus the PM (in response to late AM parking problems) show that over 50% of WAMC primary care appointments occur through the 10 AM hour and nearly 75% occur through the 1 PM hour (last 3 hours or 37.5% of day sees 25% of patients). This AM bolus of patients is compounded by random and increased pharmacy demands in the AM that could be forecasted and used to solve a majority of the WAMC parking issue. This random example demonstrates how a pervasive perspective on patient flow throughout all WAMC personnel may provide ways to improve the delivery of all WAMC patient services, and demonstrate a way to provide positive second and third order effects from projects to improve patient flow throughout the WAMC health care system.

Based on these additional, random examples, the largest future challenge for improving patient flow in the WAMC ED is the WAMC Command leadership realizing and focusing on ways to improve patient flow across the entire hospital system that encompasses all of the services that Womack Army Medical Center provides. A perfect example of this challenge is to identify ways to improve patient flow hospital-wide. Examples of improving patient flow include the OR (e.g. eliminating artificial variation to allow support staff hospital-wide to better support OR patient needs and flow), or the

inpatient wards (e.g. enacting forecasting of inpatient demands on a daily basis, and then preparing the necessary staffing and bed capacity to support those exact inpatient demands). This final future challenge will be broadened in the conclusion of this paper, but suffice it to say, patient flow in the ED cannot be realistically improved over time without a focus of the entire WAMC organization on improving patient flow throughout the interdependent services located on its campus.

Conclusion

Broadly speaking, there are four main reasons why patient flow improvements need to be done hospital-wide. First, one needs to understand the whole problem before fixing any of its pieces, especially since all WAMC patient services depend on other WAMC patient services. Therefore, one must validate the hospital-wide bottlenecks first. Second, WAMC has very limited resources to make improvements. This fact intensifies the need to identify the best projects to work on first, as well as ensuring the smaller projects within a broader goal are prioritized to complete the task. Patient flow improvements naturally identify the best projects to work on by maintaining a patient-centric focus, and efforts on something like an inpatient flow improvement system clearly identify the biggest issues to work on first. Third, there is a significant amount of WAMC personnel who do not appreciate the interdependency of all WAMC patient services. The best way to gain an appreciation of the interdependency of WAMC health care system is to complete hospital-wide patient flow improvement efforts, and do so utilizing a broad range of WAMC personnel. One cannot really optimize just a single piece of the WAMC health care system, but the ideal solutions lead to an optimization of the entire system as a whole. Fourth, so far the WAMC project improvement approaches, to include the latest Lean Six Sigma improvement techniques, have had very limited success. This limited success is probably due to having a very limited amount of resources, as well as a failure to appreciate the

interdependency of the WAMC health care system that may ideally come from patient flow improvement efforts.

References

Advisory Board (2008). *The high performance ED: Optimizing capacity and throughput to meet ever-growing demand.* Washington, DC: Advisory Board/HWorks.

Asplin, B. (2006). Measuring crowding: Time for a paradigm shift. *Academic Emergency Medicine, 13*(4), 459-461.

Benaroia, M., Elinson, R., & Zarnke, K. (2006). Patient-directed intelligent and interactive computer medical history-gathering systems: A utility and feasibility study in the emergency department. *International Journal of Medical Informatics, 8*(2), 19-27.

Blick, K.E. (2001). The essential role of information management in point-of-care/critical care testing. *International Journal of Clinical Chemistry, 307*(1-2), 159-168.

Boudreaux, E.D. & O'Hea, E.L. (2004). Patient satisfaction in the emergency department: A review of the literature and implications for practice. *Journal of Emergency Medicine, 26*(1), 13-26.

CDC (2005). *Visits to U.S. emergency departments at all-time high; number of departments shrinking.* Retrieved September 15, 2005 from http://www.cdc.gov/nchs/pressroom/05news/emergencydept.htm

Chan, T., Killeen, J., Kelly, D., & Guss, D.A. (2005). Impact of rapid entry and accelerated care at triage on reducing emergency department patient wait times, lengths of stay, and rate of left without being seen. *Annals of Emergency Medicine, 46*(6), 491-497.

Darrab, A.A., Fan, J., & Fernandes, C.M. (2006). How does fast track affect quality of care in the emergency department? *European Journal of Emergency Medicine, 13*(1), 32-35.

Green, L.V., Soares, J., Giglio, J.F., & Green, R.A. (2006). Using queuing theory to increase the effectiveness of emergency department provider staffing. *Academic Emergency Medicine, 13*(1), 61-68.

Haraden, C. & Resar, R. (2004). Patient flow in hospitals: Understanding and controlling it better. *Frontiers of Health Services Management, 20*(4), 3-15.

Holland, L., Smith, L., & Blick, K. (2005). Reducing laboratory TAT outliers can reduce emergency department length of stay. *American Journal of Clinical Pathology, 125*(5), 672-674.

IHI (2003). *Optimizing patient flow: moving patients smoothly through acute care settings.* IHI Innovation Series white paper. Boston: Institute for Healthcare Improvement.

Flanagan, T. & Haas, A.J. (2005). Planning a new emergency department: From design to occupancy. *Journal of Ambulatory Care Management, 28*(2), 177-181.

Hatfield, K. (2007). Integrated ED: A Mississipi area medical center streamlines critical patient care through EDIS. *Health Management Technology,*

Hicks, J.M., Haeckel, R., Price, C.P., Lewandrowski, K., & Wu, A.H. (2001). Recommendations and opinions for the use of point-of-care testing for hospitals and primary care: summary of a 1999 symposium. *International Journal of Clinical Chemistry, 303*(1-2), 1-17.

Holland, L.L., Smith, L.L., & Blick, K.E. (2006). Total laboratory automation can help eliminate the laboratory as a factor in emergency department length of stay. *American Journal of Clinical Pathology, 125*(5), 765-770.

Holland, L.L., Smith, L.L., & Blick, K.E. (2005). Reducing laboratory TAT outliers can reduce emergency department patient length of stay: an 11-hospital study. *American Journal of Clinical Pathology, 124*(5), 672-674.

Jensen, K., Mayer, T.A., Welch, S.J., & Haraden, C. (2007). *Leadership for smooth patient flow: Improved outcomes, improved service, improved bottom line.* Chicago: Health Administration Press.

Kelley, M.A. (1999). The hospitalist: A new medical specialty. *Annals of Internal Medicine, 130*(4), 373-375.

Kolker, A. (2008). Process modeling of emergency department patient flow: Effect of patient length of stay on ED diversion. *Journal of Medical Systems, 32*(5), 389-401.

Laskowski-Jones, L., Toulson, K., & McConnell, L. (2005). Assessing and planning for triage redesign. *Journal of Emergency Nursing, 31*(3), 315-318.

Lattimer, V., Brailsford, J., & Turnbull, J. (2004). Reviewing emergency care systems: Insights from systems dynamics modeling. *Emergency Medicine Journal, 21,* 685-691.

Lewandrowski, K. (2004). How the clinical laboratory and the emergency department can work together to move patients through quickly. *Clinical Leadership and Management Review, 18*(3), 155-159.

Lewandrowski, K., Flood, J., Finn, C., Tannous, B., Farris, A.B., Benzer, T.I., & Lee-Lewandrowski, E.L. (2008). Implementation of point-of-care rapid urine testing for drugs of abuse in the emergency department of an academic medical center: impact on test utilization and ED length of stay. *American Journal of Clinical Pathology, 129*(5), 796-801.

Litvak, E. (2005). Optimizing patient flow by managing its variability. In Berman S. (ed.): Front Office to Front Line: Essential Issues for Health Care Leaders. Oakbrook Terrace, IL: Joint Commission Resources, 91-111.

Litvak, E., Buerhaus, P.I., Davidoff, F., Long, M.C., McManus, M.L., & Berwick, D.M. (2005). Managing unnecessary variability in patient demand to reduce nursing stress and improve patient safety. *Joint Commission Journal on Quality and Patient Safety, 31*(6), 330-338.

Litvak, E. & Long, M. (2000). Cost and quality under managed care: Irreconciliable differences?. *The American Journal of Managed Care, 6*(3), 305-312.

Litvak, E., McManus, M.L., & Cooper, A. (2002). A root cause analysis of emergency department crowding and ambulance diversion in Massachusetts. *Boston University Program for the Management of Variability in Health Care Delivery*, Report to the Massachusetts Department of Public Health.

McKay, J.I. (1999). The emergency department of the future: The challenge is how we operate! *International Journal of Trauma Nursing, 25*(6), 480-488.

McManus, M.L., Long, M., Cooper, A. & Litvak, E. (2004). Queuing theory accurately models the need for critical care resources. *Anesthesiology, 100*(5), 1271-1276.

Noon, C., Hankins, C., & Cote, M. (2003). Understanding the impact of variation in the delivery of healthcare services. *Journal of Healthcare Management, 48*(2), 82-97.

Peterson, L.A., Burstin, H.R., O'Neil, A.C., Orav, E.J., & Brennan, T.A. (1998). Nonurgent emergency department visits: The effect of having a regular doctor. *Clinical Medicine, 36*(8), 1249-1255.

Potter, M. (2005). The tracking board. *Topics in Emergency Medicine, 27*(2), 145-156.

Powell, E., Khare, R., & Reinhardt, G. (2007). Using computer simulation to evaluate the effect of point-of-care testing on emergency department patient flow. *Annals of Emergency Medicine, 50*(3), 223-227.

Rathlev, N., Chessare, J., Olshaker, J., Obendorfer, D., Mehta, S., Rothenhaus, T., Crespo, S., Maguaran, B., Davidson, K., Shemin, R., Lewis, K., Becker, J.M., Fisher, L., Guy, L., Cooper, A., & Litvak, E. (2007). Time series analysis of variables associated with daily mean emergency department length of stay. *Annals of Emergency Medicine, 49*(3), 265-271.

Robert Woods Johnson Foundation (2009). *Urgent Matters, grant results.* Retrieved March 9, 2009 from http://www.rwjf.org/reports/npreports/urgent.htm.

Rowe, B., Channan, P., & Bullard, M. (2006). Characteristics of patients who leave emergency departments without being seen. *Academic Emergency Medicine, 13*(1), 45-52.

Showstack, J. (2005). The cost of providing non-urgent care in emergency departments. *Annals of Emergency Medicine, 45*(5), 493-494.

Stephens, N. (2000). One emergency department's responses to the increasingly complex challenges of patient care at century's change. *Journal of Emergency Nursing, 26*(4), 318-328.

Sun, B.C., Adams, J., Orav, E.J., Rucker, D.W., Brennan, T.A., & Burstin, H.R. (2000). Determinants of patient satisfaction and willingness to return with emergency care. *Annals of Emergency Medicine, 35*(5), 426-434.

Toulson, K., Laskowski-Jones, L., & McConnel, L. (2005). Implementation of the five-level emergency severity index in a level I trauma center emergency department with a three-tiered triage scheme. *Journal of Emergency Nursing, 31*(3), 259-264.

Welch, S.J. (2006). Definitions for ED measures standardize quality improvement. *Quality Matters, 28*(7), 8-9.

Welch, S.J. (2008). ED redesign takes study and imagination. *Emergency Management News, 88*, 21-22.

Welch, S., Augustine, J., Camargo, C.A., & Reese, C. (2006). Emergency department performance measures and benchmarking summit. *Academic Emergency Medicine, 13*(10), 1074-1080.

Wilson, M. & Nguyen, K. (2004). Bursting at the seams: Improving patient flow to help America's emergency departments. *Urgent Matters (online whitepaper).* Retrieved October 1, 2008 from http://www.urgentmatters.org/pdf/UM_WhitePaper_BurstingAtTheSeams.pdf.

Wilson, M.J., Siegel, B., & Williams, M. (2005). Perfecting patient flow: America's safety net hospitals and emergency department crowding. *Urgent Matters (online whitepaper).* Retrieved October 1, 2008 from http://www.urgentmatters.org/pdf/UM_WhitePaper_PerfectingPatientFlow.pdf.

Worthington, K. (2004). Customer satisfaction in the emergency department. *Emergency Medicine Clinics of North America, 22*(1), 87-102.

Yin, R. K. (2003). *Case study research: Design and methods (3rd edition).* Thousand Oaks, CA: Sage Publications.

Appendix A

ED Correlations by Hour of Day

		MDratio	EDlosJAN09	RNratio	MedicRatio	ClerkRatio	BedsRatio	EDlosFY09	LWOBSFY09
MDratio	Pearson Correlation	1	-.075	.777**	.699**	.714**	.874**	-.071	.074
	Sig. (2-tailed)		.728	.000	.000	.000	.000	.741	.733
	N	24	24	24	24	24	24	24	24
EDlosJAN09	Pearson Correlation	-.075	1	.272	.395	.384	.139	.930**	.741**
	Sig. (2-tailed)	.728		.198	.056	.064	.518	.000	.000
	N	24	24	24	24	24	24	24	24
RNratio	Pearson Correlation	.777**	.272	1	.972**	.973**	.938**	.249	.605**
	Sig. (2-tailed)	.000	.198		.000	.000	.000	.240	.002
	N	24	24	24	24	24	24	24	24
MedicRatio	Pearson Correlation	.699**	.395	.972**	1	.999**	.912**	.364	.710**
	Sig. (2-tailed)	.000	.056	.000		.000	.000	.080	.000
	N	24	24	24	24	24	24	24	24
ClerkRatio	Pearson Correlation	.714**	.384	.973**	.999**	1	.921**	.349	.695**
	Sig. (2-tailed)	.000	.064	.000	.000		.000	.095	.000
	N	24	24	24	24	24	24	24	24
BedsRatio	Pearson Correlation	.874**	.139	.938**	.912**	.921**	1	.109	.407*
	Sig. (2-tailed)	.000	.518	.000	.000	.000		.611	.048
	N	24	24	24	24	24	24	24	24
EDlosFY09	Pearson Correlation	-.071	.930**	.249	.364	.349	.109	1	.734**
	Sig. (2-tailed)	.741	.000	.240	.080	.095	.611		.000
	N	24	24	24	24	24	24	24	24
LWOBSFY09	Pearson Correlation	.074	.741**	.605**	.710**	.695**	.407*	.734**	1
	Sig. (2-tailed)	.733	.000	.002	.000	.000	.048	.000	
	N	24	24	24	24	24	24	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix B

ED Correlations by Day of the Week

		RNratio	MedicRatio	ClerkRatio	MDratio	EDcensus	EDlosKept	EDLWOBSavg
RNratio	Pearson Correlation	1	.271	.596**	.748**	.764**	.086	.403*
	Sig. (2-tailed)		.116	.000	.000	.000	.623	.016
	N	35	35	35	35	35	35	35
MedicRatio	Pearson Correlation	.271	1	.457**	.676**	.660**	.602**	.679**
	Sig. (2-tailed)	.116		.006	.000	.000	.000	.000
	N	35	35	35	35	35	35	35
ClerkRatio	Pearson Correlation	.596**	.457**	1	.642**	.719**	.180	.147
	Sig. (2-tailed)	.000	.006		.000	.000	.301	.401
	N	35	35	35	35	35	35	35
MDratio	Pearson Correlation	.748**	.676**	.642**	1	.972**	.405*	.620**
	Sig. (2-tailed)	.000	.000	.000		.000	.016	.000
	N	35	35	35	35	35	35	35
EDcensus	Pearson Correlation	.764**	.660**	.719**	.972**	1	.390*	.600**
	Sig. (2-tailed)	.000	.000	.000	.000		.021	.000
	N	35	35	35	35	35	35	35
EDlosKept	Pearson Correlation	.086	.602**	.180	.405*	.390*	1	.747**
	Sig. (2-tailed)	.623	.000	.301	.016	.021		.000
	N	35	35	35	35	35	35	35
EDLWOBSavg	Pearson Correlation	.403*	.679**	.147	.620**	.600**	.747**	1
	Sig. (2-tailed)	.016	.000	.401	.000	.000	.000	
	N	35	35	35	35	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix C

ED Correlations with OR and Primary Care operational figures

		InptOR1to11	InptORwOB	ORcancels	ORdelays	ORdailytotals	PCappts	EDcensus	EDavgLOS	EDadmits	EDadmitLOS	EDLWOBS
InptOR1to11	Pearson Correlation	1	.957**	.532**	.577**	.759**	.738**	.028	.341**	.253**	.117	.250**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.734	.000	.002	.153	.002
	N	151	151	151	151	151	151	151	151	151	151	151
InptORwOB	Pearson Correlation	.957**	1	.534**	.594**	.768**	.717**	-.005	.317**	.225**	.117	.231**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.952	.000	.005	.152	.004
	N	151	151	151	151	151	151	151	151	151	151	151
ORcancels	Pearson Correlation	.532**	.534**	1	.642**	.718**	.685**	-.024	.361**	.204*	.199*	.271**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.772	.000	.012	.014	.001
	N	151	151	151	151	151	151	151	151	151	151	151
ORdelays	Pearson Correlation	.577**	.594**	.642**	1	.738**	.750**	-.061	.427**	.197*	.150	.292**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.454	.000	.016	.065	.000
	N	151	151	151	151	151	151	151	151	151	151	151
ORdailytotals	Pearson Correlation	.759**	.768**	.718**	.738**	1	.931**	-.113	.398**	.225**	.148	.252**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.168	.000	.005	.070	.002
	N	151	151	151	151	151	151	151	151	151	151	151
PCappts	Pearson Correlation	.738**	.717**	.685**	.750**	.931**	1	-.094	.428**	.203*	.134	.334**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.253	.000	.012	.102	.000
	N	151	151	151	151	151	151	151	151	151	151	151
EDcensus	Pearson Correlation	.028	-.005	-.024	-.061	-.113	-.094	1	.007	.070	-.053	.228**
	Sig. (2-tailed)	.734	.952	.772	.454	.168	.253		.936	.396	.522	.005
	N	151	151	151	151	151	151	151	151	151	151	151
EDavgLOS	Pearson Correlation	.341**	.317**	.381**	.427**	.398**	.428**	.007	1	.330**	.294**	.660**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.936		.000	.000	.000
	N	151	151	151	151	151	151	151	151	151	151	151
EDadmits	Pearson Correlation	.253**	.225**	.204*	.197*	.225**	.203*	.070	.330**	1	.194*	.308**
	Sig. (2-tailed)	.002	.005	.012	.016	.005	.012	.396	.000		.017	.000
	N	151	151	151	151	151	151	151	151	151	151	151
EDadmitLOS	Pearson Correlation	.117	.117	.199*	.150	.148	.134	-.053	.294**	.194*	1	.220**
	Sig. (2-tailed)	.153	.152	.014	.065	.070	.102	.522	.000	.017		.007
	N	151	151	151	151	151	151	151	151	151	151	151
EDLWOBS	Pearson Correlation	.250**	.231**	.271**	.292**	.252**	.334**	.228**	.660**	.308**	.220**	1
	Sig. (2-tailed)	.002	.004	.001	.000	.002	.000	.005	.000	.000	.007	
	N	151	151	151	151	151	151	151	151	151	151	151

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix D

List of Acronyms

BCA – business case analysis (U.S. Army medical cost effectiveness study for capital investments)

BRAC – Base Realignment and Closure (Department of Defense reorganization of military bases)

CHCS – Composite Health Care System (legacy electronic record to capture patient encounter data)

ED – emergency department (treatment area that sees emergent/urgent patients)

EDPTA – emergency department patient tracking application (electronic patient tracking tool)

ESI – emergency severity level (5-tier system with I=emergency; II-III=urgent; IV-V=non-urgent)

FT – fast track (treatment area in ED that sees non-urgent patients)

FY – fiscal year (runs 1 Oct to 30 Sep for military budgets)

IHI – Institute of Healthcare Improvement (healthcare agency utilizing patient flow improvements)

LBTC – left before treatment complete (civilian ED metric synonymous with WAMC ED LWOBS)

LOS – length of stay (amount of time from registration to discharge)

LWOBS – left without being seen (patients depart WAMC ED prior to discharge by provider)

MA2/MA3/MA4 – moving averages of 2-4 months in length

MAD – mean absolute deviation (measure of accuracy for forecasts)

MAPE – mean absolute percent error (measure of accuracy for forecasts)

MD – medical doctor (main ED provider and possibly used in MD/PA-triage system)

OB – obstetrics (some inpatient surgeries performed in main ED are random OB demands)

OR – operating room (variation in elective surgical schedule impacts ED operations)

PA – physician assistant (FT provider and possibly used in PA-triage system)

POCT – point-of-care testing (allows for certain lab tests to be conducted at the ED or care location)

QMatic – electronic queuing system used in many military labs, pharmacies, and soon WAMC ED

RALS – remote automated laboratory system (allows for POCT lab tests to be fully automated)

S3 – surgical scheduling system (schedules elective surgeries and maintains surgical data)

TAT – turnaround time (cycle time on various ED processes from lab order to specialty consult)

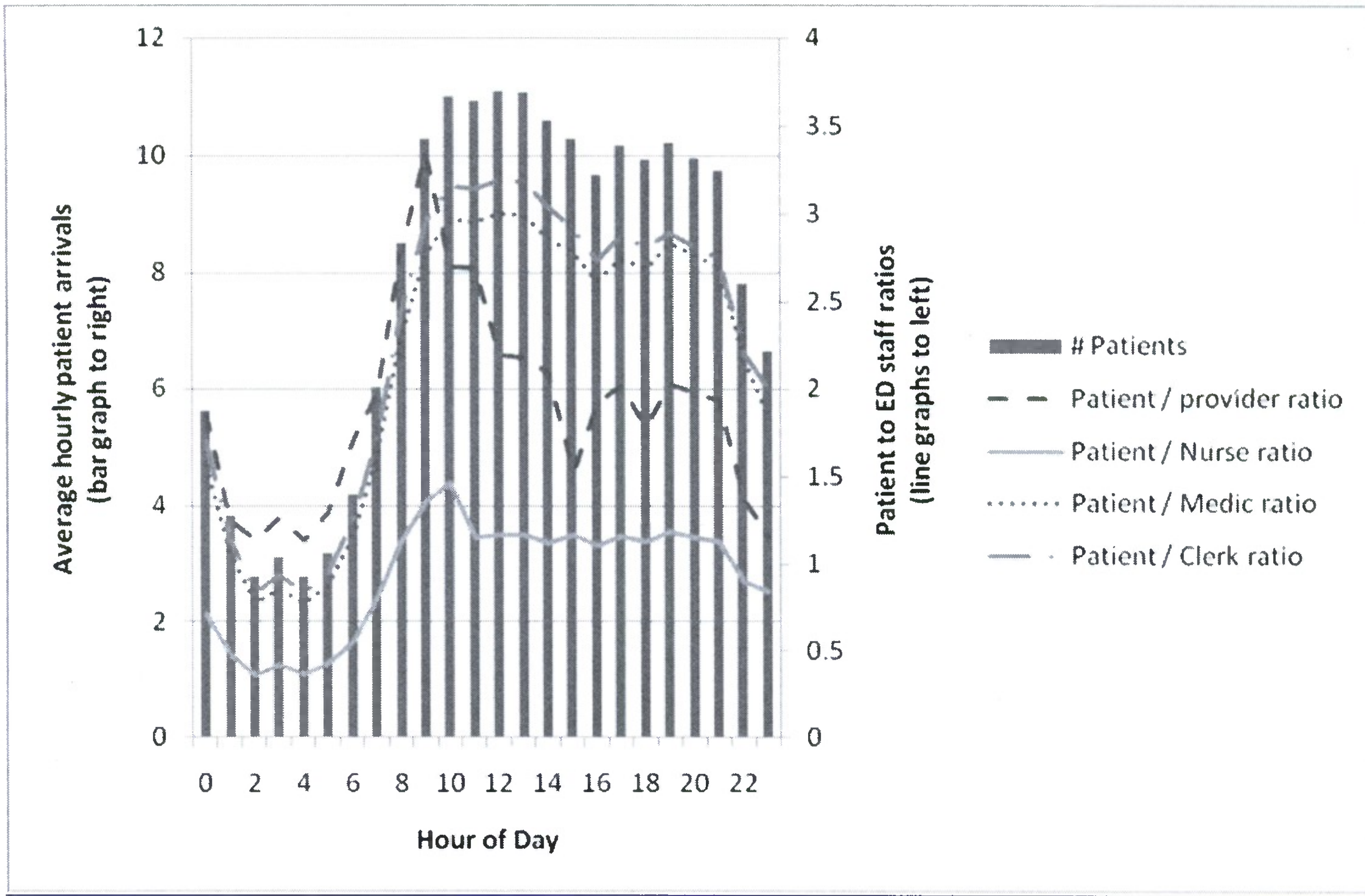
TJC – The Joint Commission (national accreditation authority for healthcare organizations)

WAMC – Womack Army Medical Center (hospital located at the 'Center of the Universe')

Appendix E

WAMC ED Demand-Capacity alignment charts

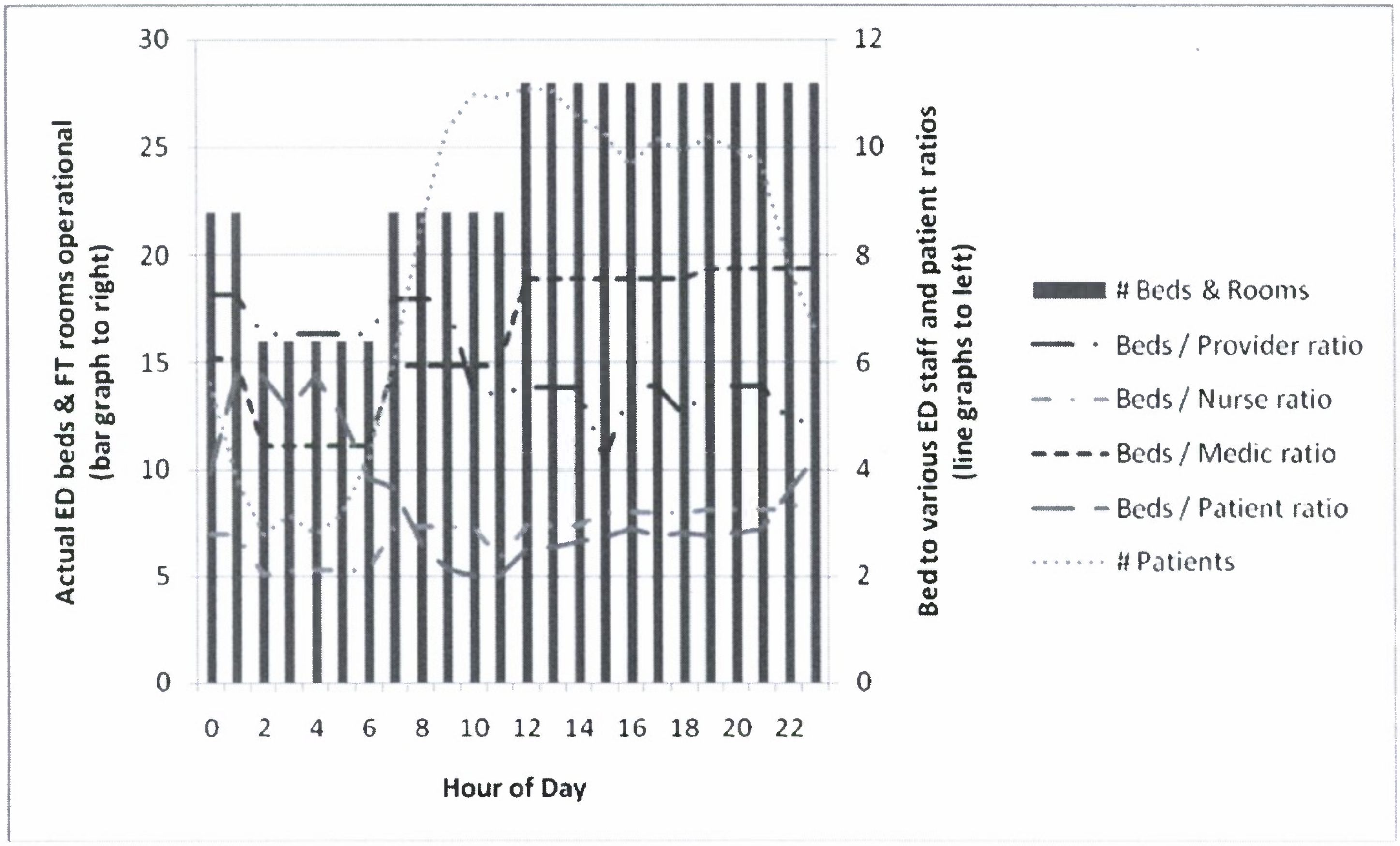
Chart 1. Hourly ED staffing ratios (graphical lines) with average patient arrivals (vertical bars)



NOTE: This chart is produced from the data in Table 20 above.

NOTE2: All graphical lines depicting various ratios should follow the changes in number of patients shown by bar graphs, if staff were perfectly aligned with number of patients arriving per hour. Solid line of nurses is best aligned with patient demands.

Chart 2. Hourly ED staffing ratios (graphical lines) with actual ED bed/FT room levels (vertical bars)



NOTE: This chart is produced from the data in Table 21 above.

NOTE2: All graphical lines (except # patients/small dotted line) depicting various ratios should follow the changes shown by bar graphs, if staff and arriving patients were perfectly aligned with number of operational ED beds & FT rooms.

NOTE3: ED patients (small dotted line) should rise and fall with ED bed/FT room levels (vertical bars). This shows from 0000-0600 too many beds/rooms in operation, and from 0800-1200 not enough beds are in operation.

NOTE4: ED staff has a standardized amount of ED beds or FT rooms of responsibility (i.e. provider per 5 ED beds, nurse per 3 ED beds). This again dictates need for all graphical lines (except small dotted line) to follow peaks and valleys shown in bar graphs and small dotted line.